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ABSTRACT

GRADES OR AGES: Grades 11 and 12. SUBJECT MATTER: Mechanical technology. ORGANIZATION AND PHYSICAL APPEARANCE: The guide is in two volumes. The first volume gives a brief outline of the course, breaking it down into divisions, units, and subunits. The second volume gives a detailed descriptin of each subunit in a seven-column layout across two pages. The first column is offset printed and staple-bound with a paper cover; the second volume is offset printed and edition bound with a soft cover. OBJECTIVES AND ACTIVITIES: General objectives for the course are outlined briefly in the first column. Each subunit description in the second volume lists several activities and teaching tips. A letter coding classifies each activity as experimental, problem solving, application study, machining exercise, or project. An introductory section presents several different methods for organization and timing of the units and subunits. INSTRUCTIONAL MATERIALS: A one-page bibliography at the end of the first volume lists references for each of the three divisions. STUDENT ASSESSMENT: No mention. (RT)

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ONTARIO DEPARTMENT OF EDUCATION

CURRICULUM S-27D

ELEMENTS OF MECHANICAL TECHNOLOGY

GRADES 11 AND 12

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FOREWORD

An integrated technical course is one in which two or more disciplines that have common or complementary content are combined into one technology. This course outline in Elements of Mechanical Technology represents an integration of subject content in the mechanical field. The outline consists of three divisions: Core, Drafting and Design, and Machine Theory and Practice. It is intended for use in Grades 11 and 12.

At the secondary school level, we are concerned with fundamentals rather than the treatment in depth which characterizes the tertiary levels of education. An integrated approach is desirable because students understand basic principles best if they are able to relate them to several subjects. The relation of various technical subjects to Mathematics, Science, English, and History should be stressed repeatedly. In this way the technical subjects become effective educational vehicles as well as a means of learning skills.

Since the course is a two-year entity the teachers must decide the extent to which any unit will be studied in either Grade 11 or Grade 12. Although the arrangement of the outline is logical, it is not chronological: it is an analysis of subject content, not a synthesis. No attempt has been made to arrange these topics in a teaching sequence nor has any attempt been made to integrate the topics of the three divisions: these tasks are reserved for the professional teacher. The need for frequent consultation among the participating teachers is imperative. If possible, one or two periods per week should be set aside so that course construction, lesson planning, and evaluation can be pursued as a team effort.

The course outline was prepared on the understanding that a total of six hundred hours was available for implementation: of this time allotment, about twenty per cent should be devoted to Division 1, and forty per cent to Divisions 2 and 3. Teachers may alter these ratios somewhat, and may omit optional topics (marked "O") in favour of other material.

Approximately sixty per cent of the available time should be devoted to student activity that reinforces theoretical aspects. The teacher may, however, increase this ratio by developing individualized, imaginative methods. The inductive, directed-discovery approach should be implemented as frequently as possible.

Students should feel that they are taking one technical subject. This may be accomplished by innumerable arrangements and varieties of presentation. To illustrate the manner in which a given topic relates to sections in all divisions, one might consider gearing. Without any selection as to sequence or to depth of treatment, gearing can be related to the following:

11.1	Metals
11.3	Material treatments
12.2	Material removal
12.4	Casting and moulding
12.7	Inspection
13.3	Drive mechanisms
21.2	Advanced projection systems
21.4	Industrial practices
23.1	Design considerations
23.2	Manufacturing considerations
23.3	Quality assurance
31.2	Milling machine operations
31.7	Shaper, planer and slotter operations
33.1	Measurement and gauging
33.2	Testing

This list illustrates the fact that the course outline offers an organization of content, but does not inhibit teachers from developing a coherent sequence related to the particular requirements of their classes and the facilities at hand.

SAFETY

The responsibility for providing technical areas that are designed and equipped from a safety point of view rests with the board of education. The maintenance of safe working and teaching conditions is the responsibility of the teacher and the technical director.

The teacher of Elements of Mechanical Technology has an excellent opportunity to condition his students so that they become "safety conscious" about all aspects of their school programs. If this goal is achieved, the students will tend to maintain this attitude of mind in all environments.

Upon request, professional accident-prevention associations will provide speakers, films, literature, and periodic inspections. A staff advisor and three or more students might form a committee to organize activities that would make the student body more aware of accident prevention. A special "safety week" is one possibility.

AIMS AND OBJECTIVES

The aims of technical education are identical with those of education as a whole: developing each student's personality and capabilities, and fostering constructive attitudes toward himself and society.

Technical subjects are viable educational vehicles that can serve effectively in the comprehensive development of youth for modern society. The focus of the technical disciplines is technology, which may be defined as the use, based on knowledge, of materials and the physical powers of nature for the purpose of serving human ends.

Some objectives of Elements of Mechanical Technology are:

- To encourage creative expression within the medium of science and technology
- To develop a positive attitude toward learning
- To reveal the close relation of the humanities, sciences, and the technologies
- To kindle a "childlike" curiosity which will find expression in a continuing thirst for knowledge about mechanical devices
- To make the student aware of a continually changing technological world
- To instill in the student a degree of confidence in his ability to comprehend complex industrial machines and processes
- To convey the fact that mature attitudes and good work habits enable the individual to achieve job satisfaction
- To provide an overview of Canadian industry, particularly with regard to mechanical technology
- To contribute to a sound educational base from which further education and training may proceed
- To prepare for employment by the development of basic technical skills

The teachers of Elements of Mechanical Technology are asked to keep these immediate objectives in mind at all times so that the student will be competent to:

- work amicably with others
- do individual research and work independently of supervision
- seek mathematical solutions to problems whenever possible
- plan his work schedule
- appreciate and practice good safety practices
- visualize and draw mechanical components
- relate assembly and detail drawings to production techniques
- prepare complete and accurate technical reports
- develop skill in discussion of technical topics
- use measuring and testing equipment competently
- diagnose mechanical failures
- perform basic machine operations

COURSE ORGANIZATION

DIVISION 1: CORE

Unit 1.1 Materials
Section 11.1 Metals
11.2 Non-Metals
11.3 Material Treatments

Unit 1.2 Manufacturing Methods and Processes
Section 12.1 Industrial Organization
12.2 Material Removal
12.3 Material Working
12.4 Casting and Moulding
12.5 Fabrication
12.6 Surface Coatings and Finishes
12.7 Inspection

Unit 1.3 Transmission of Power
Section 13.1 Shafts and Bearings
13.2 Lubrication
13.3 Drive Mechanisms
13.4 Fluid Power
13.5 Electrical Power

DIVISION 2: DRAFTING AND DESIGN

Unit 2.1 Graphic Representation
Section 21.1 Basic Drawing
21.2 Advanced Projection Systems
21.3 Technical Charts and Graphs
21.4 Industrial Practices

Unit 2.2 Applied Mechanics
Section 22.1 Forces
22.2 Statics

Unit 2.3 Design Evaluation
Section 23.1 Design Considerations
23.2 Manufacturing Considerations
23.3 Quality Assurance
23.4 Creative Design Problems

DIVISION 3: MACHINE THEORY AND PRACTICE

Unit 3.1 Machining Operations
Section 31.1 Lathe
31.2 Milling Machine
31.3 Drilling Machines
31.4 Sawing and Filing Machines
31.5 Grinding and Precision Finishing
31.6 Jig Boring
31.7 Shaping, Planing and Slotting
31.8 Special Processes

Unit 3.2 Bench Operations
Section 32.1 Layout
32.2 Fitting and Assembling

Unit 3.3 Metrology
Section 33.1 Measurement and Gauging
33.2 Testing

DIVISION 1: CORE

INTRODUCTION

This division identifies three units of the course common to both mechanical drafting and machine theory and practice: Materials, Manufacturing Methods and Processes, and Transmission of Power form a division that makes it mandatory for the two teachers concerned to develop the course of study together. It is quite possible that both teachers will present some information on all topics. The co-operation thus required for the construction of the course for Division 1 should be continued for Divisions 2 and 3.

Treatment of the Metals and Non-Metals Section should provide the student with an understanding of possible applications for these materials, based upon their chemical and physical characteristics. A study of manufacturing methods and processes will give a broad overview of Canadian industry and indicate employment trends and opportunities.

Unit 1.3, Transmission of Power, explores a wide spectrum of topics. The depth of treatment of any one topic must be decided by the teacher. It is expected, however, that gearing and cams will receive greater treatment than power screws or differential mechanisms. Since fluid power applications are becoming commonplace, the basic principles underlying this power source should receive special attention.

At first glance, the section headings might suggest a purely academic approach to methods of presentation. Upon further study, the teacher will realize that this division is ideally suited to the use of modern, imaginative techniques that may provide sixty to seventy per cent of classroom time for student activity. The discovery approach, classroom and home experiments, research projects, group discussions, field trips, and work experience programs may all be used to supplement formal lessons. Additional equipment and resource material will be necessary if a student-centred approach is to be maintained.

Liaison with other departments of the school, science in particular, will enhance the educational value of this division. Many topics will become more significant for the student if integration with other subjects can be achieved on a broad scale throughout the Grades 11 and 12 curriculum.

UNIT 1.1 MATERIALS

Metals
  Ferrous
  Non-Ferrous

Non-Metals
  Plastics
  Elastomers (O)
  Miscellaneous (O)

Material Treatments
  Property Changes
  Thermal
  Mechanical

UNIT 1.2 MANUFACTURING METHODS AND PROCESSES

Industrial Organization
- Types of Industries
- Company Structure
- Production and Marketing (O)
- Industrial Relations (O)
- Trends in Canadian Industry (O)

Material Removal
- Conventional Cutting Tools and Processes
- Special Processes (O)

Material Working
- Forging
- Extruding
- Stamping
- Bending and Forming
- Drawing
- Spinning

Casting and Moulding
- Gravity Casting (sand)
- Investment Casting
- Pressure Casting
- Moulding of Plastics
- Powdered Metallurgy

Fabrication
- Welding
- Riveting
- Threaded Fasteners
- Miscellaneous Fasteners (O)
- Adhesives (O)

Surface Coatings and Finishes
- Mechanical and Thermal Diffusion
- Electroplating
- Heat and Chemical Conversion

Inspection
- Definition and Purpose
- Tolerances
- Measuring Practice

UNIT 1.3 TRANSMISSION OF POWER

Shafts and Bearings
- Principles
- Shafts
- Sliding Bearings
- Rolling Contact Bearings

Lubrication
- Fundamentals
- Fluid
- Grease and Solids
- Seals
- Systems (O)

Drive Mechanisms
- Gearing
- Cams
- Couplings
- Clutches
- Brakes
- Flexible Drives
- Miscellaneous Mechanisms (O)

Fluid Power
- Basic Principles
- Pneumatics
- Hydraulics
- Fluidics (O)

Electrical Power (O)
- Basic Principles
- Rotating Machines
- Transformers
- Control Systems

DIVISION 2: DRAFTING AND DESIGN

INTRODUCTION

The advantages of the integrated program become more apparent as the teacher presents the course of study. Topics such as working drawings, tolerances, threads, and gears are enhanced because the student must make calculations and use detail drawings in machining an object. The student who is employed in a drafting office will make a better contribution to any group effort if he understands various machining processes: these advantages can be given particular emphasis by the teacher of mechanical drafting.

The Section on Basic Drawing provides a brief review of the work covered in Grades 9 and 10 since timetabling arrangements can cause variation in the drafting abilities of Grade 11 students. Considerable time is allotted to the study of geometrical constructions, technical sketching, elementary projections, sectioning, dimensioning and tolerances, working drawings, and reproduction methods. A variety of student assignments designed to develop motor skills and spatial concepts will reinforce this section. The study of graphic reproduction methods such as microfilming, photographic processes, wet processes, and dry processes should be included.

The treatment of Industrial Applications is broad in scope. The teacher should emphasize the topics which relate to local industry. Field trips and work experience programs are ideally suited to reinforce the study of gears and cams, mechanisms, casting and forging design, and drafting office routines. Research assignments would permit the interested student to explore in depth, topics that have been given limited coverage because of time restrictions.

The tendency to present Statics as a series of lectures must be resisted. Individual students should undertake simple experiments on a basic material such as steel in order to understand the types of forces.

Design Evaluation introduces the fundamental problems and conditions which must be met before a manufactured product can be marketed successfully. Opportunities for the teacher to break away from traditional methods of lesson presentation are enhanced by the nature of the content of this unit. Individual student study should be encouraged. Visits to local industries as well as consultation with produce engineers and other industrial personnel will enrich this part of the course.

Although no topics have been listed under Creative Design Problems, this section is included because students should be given the opportunity to attempt creative solutions to realistic technological problems. The situations requiring resolution may range over the entire course and beyond: they may relate to the locality or to a student's particular interest. They may demand many skills: mathematical, graphical, aesthetic, and manipulative. Since the possibilities are endless, no specific problems have been suggested.

UNIT 2.1 GRAPHIC REPRESENTATION

Basic Drawing
- Geometrical Construction
- Technical Sketching
- Elementary Projections
- Sectioning
- Dimensioning and Tolerances
- Working Drawings
- Reproduction of Drawings

Advanced Projection Systems
- Auxiliary Views
- Revolutions
- Axonometric Projection (O)
- Oblique Projection
- Perspective Projection (O)
- Intersections and Developments

Technical Charts and Graphs
- Types of Charts and Graphs
- Engineering Graphics

Industrial Practices
- Drafting Office Routine
- Structural
- Electrical and Electronic (O)
- Casting and Forging
- Threads, Fasteners, and Springs
- Gears and Cams
- Mechanisms
- Tool Drawings
- Welding
- Piping (O)
- Fluid Power
- Technological Innovations:
  - Display, Plotter and Reduction Systems (O)

UNIT 2.2 APPLIED MECHANICS

Forces
- Description
- Types
- Vector Analysis
- Turning Effects
- Equilibrium of Forces

Statics
- Tensile
- Compressive
- Shear
- Bending Moments
- Twisting Moments (O)
- Failure under Load

UNIT 2.3 DESIGN EVALUATION

Design Considerations
- Aesthetic Features
- Functional Features

Manufacturing Considerations
- Available Methods and Processes
- Selection of Materials
- Costs

Quality Assurance
- Relationship to Design
- Quality Control

Creative Design Problems

DIVISION 3: MACHINE THEORY AND PRACTICE

INTRODUCTION

Although sophisticated machine tools are available, industry is unable to realize their potential because of a lack of trained personnel. One objective of this division is to provide graduates who will fill this gap. Many of the latest machining processes have been included under special processes. The treatment of hydraulic tracers, mechanical tracers, electro-discharge machining (E.D.M.) and others is not intended to be exhaustive. The students should see these operations during a field trip or under some other special arrangement; they should then be encouraged to undertake independent study and research within this unit.

Integration of content between Divisions 2 and 3 will require considerable skill by participating teachers. Machining exercises rather than projects will facilitate the transition of ideas and concepts from drafting board to finished product; for example, the study of threads in the drafting room will become more significant to the student if he is required to produce two or three short test threads in the machine shop.

Several advantages of successful integration between Divisions 2 and 3 have already been mentioned in the Foreword. Three others should be mentioned:

- The student who ultimately wishes to enter a tool room or machine shop will find that his ability to interpret drawings, to foresee possible design weaknesses, and to pick out actual mistakes on drawings and blueprints is sharpened by the dual purpose concept of this course.
- The student desirous of entering a machine design or a mechanical design drafting office will find that his improved background knowledge in basic machine tool operations and material treatment will contribute much to his success as a draftsman.
- Teachers who take the time to plan for student activity whereby knowledge and skills gained in the drafting room or machine shop are applied to the other subject area increase their own understanding of their subject field, and may encourage other staff members to explore the possibilities of integrating other subjects of the curriculum.

UNIT 3.1 MACHINING OPERATIONS

Lathe
- Turning
- Hole Production
- Threading
- Work Holding Devices
- Cutting Tools and Tool Holding Devices

Milling Machine
- Standard Milling Operations
- Form Milling Operations
- Indexing Operations
- Attachments and Work Holding Devices

Drilling Machines
- Operations
- Hole Finishing

Sawing and Filing Machines
- Sawblade Selection
- Sawing
- Filing

Grinding and Precision Finishing
- Work Holding Devices
- Grinding Wheels
- Standard Grinding Operations
- Super Finishing (O)

Jig Boring
- Introduction
- Operation
- Applications

Shaping, Planing, and Slotting
- Operations
- Work Holding Devices

Special Processes
- Tracers
- Turret Lathe
- Screw Machines (O)
- Boring Mills (O)
- Numerical Control
- Electro-Discharge Machining (E.D.M.)
- Electro-Chemical Machining (E.C.M.)
- Ultra-Sonic Machining (U.S.M.) (O)

UNIT 3.2 BENCH OPERATIONS

Layout
- Surface Preparation
- Tools and Equipment

Fitting and Assembling
- Cutting Tools
- Assembly Devices and Methods

UNIT 3.3 METROLOGY

Measurement and Gauging
- Science of Measurement
- Measuring Instruments
- Gauging Equipment

Testing
- Non-Destructive
- Destructive

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ELEMENTS OF MECHANICAL TECHNOLOGY

CURRICULUM GUIDE
SUPPLEMENT TO S27D

ONTARIO DEPARTMENT OF EDUCATION

1969

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USE OF THE CURRICULUM GUIDE

This publication is a teachers' guide that expands Elements of Mechanical Technology, Curriculum S-27D. Teachers may use the additional material to whatever degree they wish: they should not consider the Guide as mandatory subject content.

All Divisions, Units, Sections, and Topics are identical to those that appear in Curriculum S-27D. Note that (O) indicates optional material.

The Elements column continues the analytical breakdown beyond the Topics level. It completes the exploded-view concept in which each Division is analyzed in a series of five steps, each step representing a dissection of the former. Thus, Section content is made explicit by its associated Topics and each Topic is made explicit by its associated Elements.

A numbering system is used to designate each subdivision of the course. It is organized in such a way that, reading from left to right:

- The first number indicates the Division
- The second number indicates the Unit
- The third number indicates the Section
- The fourth number indicates the Topic
- The fifth number indicates the Element

As an example of this arrangement, 1132.1 refers to Division 1, Unit 1, Section 3, Topic 2, and Element 1. The number of digits denotes the degree of breakdown: as a case in point, 32.2 indicate Section 2, Unit 2 or Division 3.

Although each Unit, Section, and Topic is developed in a logical manner, **no attempt has been made to divide the course into "lessons" nor does the Guide provide the teacher with a chronological sequence.** Since the complete two-year course is treated as an entity, the arrangement of subject material into weekly, monthly, and yearly sequences is the task of the teachers. They must shape the subject content into a cohesive pattern in which relationships and principles are stressed.

The Cross-Reference column utilizes the numbering system to facilitate integration of the course as a whole. Many of the possible cross-references have been listed. Undoubtedly the teacher will add or delete according to his own perspective. The numbers do not necessarily correspond to the element which appears in the same horizontal line: they relate to the topic or element with which they are associated. No precise alignment was possible.

The Fundamentals column contains the basic concepts and principles which make the study of mechanical technology a formative educational experience. This column is an attempt to generalize from the particular Section, Topic, and Element material; it is **not** a further breakdown of the Elements. Concepts, principles, laws, and rules are included, along with the relevant mathematical expressions. Obviously, if a student gains a clear grasp of these fundamentals, he will possess a sound foundation for study in mechanical technology.

The concepts that have a (C) after them are those which have broad applications in several disciplines or fields. For example, "feedback" occurs in a wide range of physical and social contexts.

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The Cross-Reference column utilizes the numbering system to facilitate integration of the course as a whole. Many of the possible cross-references have been listed. Undoubtedly the teacher will add or delete according to his own perspective. The numbers do not necessarily correspond to the element which appears in the same horizontal line: they relate to the topic or element with which they are associated. No precise alignment was possible.

The Fundamentals column contains the basic concepts and principles which make the study of mechanical technology a formative educational experience. This column is an attempt to generalize from the particular Section, Topic, and Element material; it is **not** a further breakdown of the Elements. Concepts, principles, laws, and rules are included, along with the relevant mathematical expressions. Obviously, if a student gains a clear grasp of these fundamentals, he will possess a sound foundation for study in mechanical technology.

The concepts that have a (C) after them are those which have broad applications in several disciplines or fields. For example, "feedback" occurs in a wide range of physical and social contexts.

The Technical Terms column consists of a list of those technical terms that the students must understand in order to grasp the topic under consideration. Many of these items need to be formally defined: others may only require familiarity on the part of the student.

Student activities of several kinds are suggested. These refer to activities which the student performs without direct supervision and frequently include the use of hardware. The letter (E) after the title indicates an experiment to be done; the letter (X) denotes problem-solving periods devoted to calculations done on paper; the letter (A) refers to an "application-study" in which the student is directed to scrutinize an industrial application or applications, particularly as to design features; the letters (ME) signify a machining exercise and appear only in Division 3; the letter (P) designates a project of some kind. Teachers should encourage their students to embark upon major projects which involve knowledge from several Divisions; such projects provide a valuable integrating experience and relate to real-life situations.

Note that student activity should exceed fifty per cent of the time available. Learning situations in which the individualized, inductive approach is possible should increase this ratio considerably. Whatever the methods, student comprehension is the main aim rather than completion of course content.

The Discussion column is an attempt to communicate relevant information or ideas not conveyed elsewhere. Items are clarified or amplified and some suggestions as to method are proposed.

COURSE IMPLEMENTATION

The complete course as suggested in this Guide can be implemented in approximately 600 hours of student time, spread over a two-year period. This would appear to meet the needs of the committed students who intend to seek employment or advance to a college of applied arts and technology upon graduation.

We must, however, adjust also to the requirements of other students who may wish a modified program. The chart on this page indicates some of the possible courses which can be drawn from Curriculum S-27D and this Guide.

If a local administration wishes to offer additional packages, these courses should be defined on the basis of the needs of the student.

POSSIBLE COURSE DESIGNATIONS	CONTENT	APPROXIMATE DURATION		TEACHER REQUIREMENTS	
		YEARS	HOURS		
Elements of Mechanical Technology I	Divisions 1, 2, & 3	Two	600	Two	An i wish The (pro broa
Elements of Mechanical Technology II	Divisions 1, 2, & 3	Two	300	Two	An i for u
Elements of Mechanical Technology III	Divisions 1 & 2	Two	240	Two	A tr omit exer dent cove it fo
Elements of Mechanical Technology IV	Divisions 1 & 3	Two	240	Two	A tr omit and a pa cove, for o
Materials and Processes	Division 1	One	120	One or Two	A co know dust
Graphic Representation	Division 2	One	120	One	A co insig eral
Machine Theory and Practice	Division 3	One Half	60	One	A se whic

LE COURSE NATIONS	CONTENT	APPROXIMATE DURATION		TEACHER REQUIREMENTS	COMMENT
		YEARS	HOURS		
of Mechanical nology I	Divisions 1, 2, & 3	Two	600	Two	An integrated technical course for the student who wishes to major in mechanical studies. The graduate might proceed to tertiary education (probably to a C.A.A.T.) or seek employment in the broad field of applied mechanics.
of Mechanical nology II	Divisions 1, 2, & 3	Two	300	Two	An integrated technical course primarily intended for university-bound students.
of Mechanical ology III	Divisions 1 & 2	Two	240	Two	A truncated version which permits the student to omit machine theory and practice. Some machining exercises should be introduced as part of the student activity in Division 1. Although the course covers two years the student might elect to take it for one year only.
of Mechanical ology IV	Divisions 1 & 3	Two	240	Two	A truncated version which permits the student to omit the Drafting and Design Division. Sketching and blueprint reading assignments should become a part of student activity. Although the course covers two years, a student might elect to take it for one year only.
and Processes	Division 1	One	120	One or Two	A course for the student who wishes to gain a knowledge of materials and processes used in industry.
epresentation	Division 2	One	120	One	A course for the student who wishes to obtain an insight into mechanical drafting as part of his general education.
ory and Practice	Division 3	One Half	60	One	A semestered course of a very practical nature in which basic machine shop practices are taught.

DIVISION 1: Core

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Section	Topic	Element	C Re
11.1 Metals	**111.1 Ferrous**	1111.1 Procurement	23
		1111.2 Refining	231
		1111.3 Production of iron and	123
		steel shapes	123
		1111.4 Classification systems	
		1111.5 Properties of commercial products	33
		1111.6 Stock sizes, shapes, and finishes	214
		1112.1 Procurement	1
		1112.2 Refining	2
		1112.3 Production of non-ferrous metal shapes	12
		1112.4 Classification systems Aluminum Copper Nickel Zinc Magnesium Carbide	
		1112.5 Properties of commercial products	3
		1112.6 Stock sizes, shapes, and finishes	21

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UNIT: 1.1 Materials

Topic	Element	Cross-Reference	Technical Terms
Ferrous	1111.1 Procurement	232.2	Steel-making processes
	1111.2 Refining	2312.4	Properties
	1111.3 Production of iron and steel shapes	1234.3 1235.1	A.I.S.I. S.A.E.
	1111.4 Classification systems	12.3	A.S.T.M.
	1111.5 Properties of commercial products	332.2	
	1111.6 Stock sizes, shapes, and finishes	2147.2	
	1112.1 Procurement	111.1	Refining processes
	1112.2 Refining	232.2	F.E.O.
	1112.3 Production of non-ferrous metal shapes	1235.1	A.A. A.M.S.
	1112.4 Classification systems		C.S.A.
	Aluminum		
	Copper		
	Nickel		
	Zinc		
	Magnesium		
	Carbide	12.3	
	1112.5 Properties of commercial products	332.2	
	1112.6 Stock sizes, shapes, and finishes	2147.2	

Fundamentals	Suggestions for Student Activity	
A binary alloy of iron and carbon Alloying elements in controlled amounts affect all properties Classification systems (C)	**IRON AND STEEL (A) (E)** • make an on sight study of iron and steel manufacturing. • do a research assignment on the classification of steel. • discover the machining characteristics of various alloy steels. **HANDBOOKS (A)** • use handbooks in selection of materials to meet specific requirements.	The processing o studied in depth. (aluminum, brass that involve diffe your coverage.
Refining (C)	**PROPERTIES (A) (E)** • study the properties of common ferrous and non-ferrous alloys. • use a variety of manufactured metal objects, to justify or criticize the designer's choice of material. • compare the following three cutting tool materials: carbon tool steel, high speed steel and tungsten carbide with regard to cutting speed, tool life and surface finish obtained.	

Suggestions for Student Activity	Discussion
AND STEEL (A) (E) ke an on sight study of iron and steel manufacturing. a research assignment on the classification of steel. cover the machining characteristics of various alloy steels. **DBOOKS (A)** e handbooks in selection of materials to meet specific re-ments.	The processing of steel, one of our basic engineering materials, should be studied in depth. In addition, the refining and processing of other materials (aluminum, brass, copper and others) should be introduced. Any processes that involve different techniques or basic principles should be included in your coverage.
ERTIES (A) (E) dy the properties of common ferrous and non-ferrous alloys. e a variety of manufactured metal objects, to justify or criti-he designer's choice of material. mpare the following three cutting tool materials: carbon tool , high speed steel and tungsten carbide with regard to g speed, tool life and surface finish obtained.	

DIVISION 1: Core

Section	Topic	Element
11.2 Non-metals	112.1 Plastics	1121.1 Procurement 1121.2 Properties of natural, protein and synthetic plastic type materials
	112.2 Elastomers (O)	1122.1 Natural rubber and its processing 1122.2 Artificial elastomers
	112.3 Miscellaneous (O)	1123.1 Properties of commercial products: Ceramics Wood Glass Textiles Adhesives
11.3 Material treatments	113.1 Property changes	1131.1 Structural transformation

UNIT: 1.1 Materials

Topic	Element	Cross-Reference	Technical Terms
1 Plastics	1121.1 Procurement 1121.2 Properties of natural, protein and synthetic plastic type materials	124.4 232.2	Petro-chemical refining Moulding Extruding Laminating Phenolic Polystyrene Vinyl Polyethylene Epoxy Silicone Cellulose acetate Polymer Copolymer Polymerization Thermoplastic Thermosetting Reinforced plastics
2 Elastomers (O)	1122.1 Natural rubber and its processing 1122.2 Artificial elastomers	232.2 125.5	Synthetic
3 Miscellaneous (O	1123.1 Properties of commercial products: Ceramics Wood Glass Textiles Adhesives	232.2	Ceramic Wood Glass Textile Adhesive
1 Property changes	1131.1 Structural transformation	3115.1	Grain structure Decalescent point Recalescent point Martensite Pearlite Austenite Critical points

Fundamentals	Suggestions for Student Activity	Di
Plastic	**PLASTIC COMPONENTS (P)** • produce plastic components by machining and other processes. **PROPERTIES (A)** • study properties of various plastics and their application.	A polymer or copolymer which condition or can be reheated an This section is meant to provid the source and processing of d should have an understanding materials from their source. S materials and how chemical de acteristics. Because of this ch with the study of Chemistry in The extent to which plastics ar replacing other materials in discussed. The various processes by whic be discussed with similarities t In depth studies of the reaso materials for particular applicat
Resilience	**PROPERTIES (A)** • study properties of elastomers and miscellaneous materials and their application.	The use of these engineering m each has properties which dicta
Atomic structure Lattices Transformation points Crystallization	**METCALF EXPERIMENT (E)** • show the effect of different degrees of heat on the strength, appearance and hardness of heated and quenched tool steel.	Emphasis should be placed on t result of the various treatment the physical properties of mate

ggestions for Student Activity	Discussion
PONENTS (P) tic components by machining and other processes. **A)** ties of various plastics and their application.	A polymer or copolymer which either solidifies permanently from a molten condition or can be reheated and resolidified. This section is meant to provide the student with a basic understanding of the source and processing of different engineering materials. The student should have an understanding of the development of these engineering materials from their source. Some time should be devoted to synthetic materials and how chemical deviation can provide a wide variety of characteristics. Because of this chemical deviation, a close liaison is desired with the study of Chemistry in Grade 12. The extent to which plastics are making inroads as engineering materials, replacing other materials in many common applications, should be discussed. The various processes by which plastic components are produced should be discussed with similarities to known processes being stressed. In depth studies of the reasons why plastics are selected over other materials for particular applications should be undertaken.
A) rties of elastomers and miscellaneous materials cation.	The use of these engineering materials in design should not be overlooked: each has properties which dictate its selection over others.
ERIMENT (E) fect of different degrees of heat on the strength, d hardness of heated and quenched tool steel.	Emphasis should be placed on the structural changes that take place as the result of the various treatment processes. These changes profoundly affect the physical properties of material.

DIVISION 1: Core

Section	Topic	Element
11.3 Material treatment (continued)	**113.2 Thermal**	1132.1 Hardening and tempering
		1132.2 Annealing
	113.3 Mechanical	1133.1 Work hardening

UNIT: 1.1 Materials

Topic	Element	Cross-Reference	Technical Terms
Thermal	1132.1 Hardening and tempering	3321.1	Thermocouple Pyrometer Spheroidizing Nitriding Cyaniding Carburizing Induction hardening Precipitation hardening Age hardening Quenching Isothermal treatments
	1132.2 Annealing		Normalizing Martempering Austempering
Mechanical	1133.1 Work hardening	33.2	Strain Rupture

Fundamentals	Suggestions for Student Activity	Disc
Structural transformation of metal under controlled thermal conditions Hardness (C)	**HARDENING (P)** • harden and temper an object. • case harden an object. **ANNEALING (P)** • anneal an object.	Time and equipment available may related to material treatments. Th why a particular treatment is used.
The changing of a material's properties through the action of cold working	**WORK HARDENING (E)** • demonstrate work hardening by simple mechanical action such as shearing, peening, forging.	Field trips are one of the best wa

gestions for Student Activity	Discussion
) mper an object. n object.) ect.)	Time and equipment available may permit the performing of all procedures related to material treatments. The student should be aware of the reasons why a particular treatment is used.
IING (E) work hardening by simple mechanical action such ning, forging.	Field trips are one of the best ways to illustrate material treatments.

DIVISION 1: Core

UNIT: 1.2 Manufacturing

Section	Topic	Element
12.1 Industrial organization	**121.1 Types of industries**	1211.1 Manufacturing 1211.2 Processing 1211.3 Service
	121.2 Company structure	1212.1 Kinds of ownership 1212.2 Financing 1212.3 Organization charts (to department level)
	121.3 Production and marketing	1213.1 Classification of personnel involved 1213.2 Production flow chart 1213.3 Kinds of production: job, batch, mass 1213.4 Marketing considerations 1213.5 Budgets
	121.4 Industrial relations	1214.1 Unions 1214.2 Contract negotiations and agreements 1214.3 Legal rights of labour and management
	121.5 Trends in Canadian industry	1215.1 New industries 1215.2 Growth factors 1215.3 Relative economic importance of main industries

UNIT: 1.2 Manufacturing Methods and Processes

Topic	Element	Cross-Reference	Technical Terms
Types of industries	1211.1 Manufacturing 1211.2 Processing 1211.3 Service		Foundries Heavy, medium and light fabrications Assembly plants Canning industries Refining industries Mills — various Power plants
Company structure	1212.1 Kinds of ownership 1212.2 Financing 1212.3 Organization charts (to department level)	213.1	Single ownership Partnership Limited liability Public ownership Crown corporations
Production and marketing	1213.1 Classification of personnel involved 1213.2 Production flow chart 1213.3 Kinds of production: job, batch, mass 1213.4 Marketing considerations 1213.5 Budgets	233.2 213.1 23.1	Occupational names Unit costs and sub-divisions Amortization
Industrial relations	1214.1 Unions 1214.2 Contract negotiations and agreements 1214.3 Legal rights of labour and management	232.3	Arbitration Conciliation Strike, lockout Walkout Check-off Closed shop Credit unions
Trends in Canadian industry	1215.1 New industries 1215.2 Growth factors 1215.3 Relative economic importance of main industries	213.1	G.N.P., N.N.P.

Fundamentals	Suggestions for Student Activity	
	SURVEY OF INDUSTRY (P) • make a survey of industry in the immediate area, listing these into types.	The local industrial comple vide ample material for anal In addition to the detailed a possible development of th reflect employment opportu
Legal structures Operational structures	**ANALYSIS OF INDUSTRIES (X)** • analyze and determine from the previously compiled lists, the type of ownership and structure of these industries.	
Volume and cost factors Supply and demand Sales promotion	**PRODUCTION AND MARKETING (X)** • prepare from the previous data, a particular company's production and marketing considerations.	
Bargaining rights Social systems	**INDUSTRIAL RELATIONS (P)** • define the various technical terms used in industrial relations. • classify a recent local event in this area of industrial relations.	
Evolution of industrial societies and organizations Productivity growth	**CANADIAN INDUSTRY (X)** • select from the business section of newspapers, articles which predict trends in Canadian industry and be prepared to debate these.	Students should get some industry.

ggestions for Student Activity	Discussion
IDUSTRY (P) ey of industry in the immediate area, listing these	The local industrial complex, whether in a rural or urban area, should provide ample material for analysis and study. In addition to the detailed analysis, as per student activity, a study of the possible development of the local area could be undertaken. This would reflect employment opportunities and student goals.
INDUSTRIES (X) determine from the previously compiled lists, the . hip and structure of these industries.	
AND MARKETING (X) n the previous data, a particular company's produc- ting considerations.	
ELATIONS (P) arious technical terms used in industrial relations. cent local event in this area of industrial relations.	
DUSTRY (X) the business section of newspapers, articles which in Canadian industry and be prepared to debate	Students should get some idea of the scope of the Canadian mechanical industry.

DIVISION 1: Core

UNIT: 1.2 Manufacturing M

Section	Topic	Element
12.2 Material removal	**122.1 Conventional cutting tools and processes**	1221.1 Mechanics of cutting 1221.2 Basic principles of friction lubrication and wear: efficiency 1221.3 Cutting fluids 1221.4 Tool types 1221.5 Applications
	122.2 Special processes	1222.1 Grinding, lapping, and honing

UNIT: 1.2 Manufacturing Methods and Processes

Topic	Element	Cross-Reference	Technical Terms
Conventional cutting tools and processes	1221.1 Mechanics of cutting	222.1	Chip formation and types
	1221.2 Basic principles of friction lubrication and wear: efficiency	222.2	Machinability
		222.3	Shear
	1221.3 Cutting fluids	124.5	Rakes, relief and clearance angles
	1221.4 Tool types	233.2	Heat dissipation
	1221.5 Applications	127.1	Built-up edge
		127.2	S.F.M.
			Chip breaker
		31.1	Inserts
		31.2	Surface finish
		31.3	Horsepower
		31.4	Mineral
		31.7	Emulsion coolant
			Synthetic
		31.8	Solubility
			Pre-set tooling
			Throw-away bits
			Drills, taps, dies, reamers, chasers, hobs, broaches, milling cutters
			Single point
			Multiple tools
			Tolerance
			Tool life and wear
			Cratering
			Shock resistance
Special processes	1222.1 Grinding, lapping, and honing	315.2	Abrasive
		3154.1	Microfinish
		3154.2	A.A., R.M.S.
			Grain size and grade
			Bond
			Profile
			Burn
			Checks
			Chip control
			Dresser

Fundamentals	Suggestions for Student Activity	
Material characteristics Cutting tool geometry Cutting tool material Generation of heat Lubrication Feasibility (C) Dimensional stability Stability (C)	**CONVENTIONAL PROCESSES (A) (E)** • make a comparison between the machining characteristics of various machine tools, e.g., engine lathe vs. turrett lathe; shaper vs. milling machine; vertical mill vs. horizontal mill. • make an experimental study of cutting tool geometry as it relates to efficiency. • make a comparison study between a multi-tooth and single tooth milling cutter. • study material removal with regard to: surface quality, size control, hardness, intricacy of shape, productivity.	The student may do a spec tools as part of a major block could be machined o Machining exercises coul research findings which r multi-tooth cutters.
Material removal by means of abrasives Friction	**GRINDING, LAPPING AND HONING (A)** • make a study of manufactured abrasives and their applications. Place particular emphasis on aluminum oxide and silicon carbide. • compare grinding, lapping and honing as three methods of finishing metal parts.	The student should be mad for basic machining operat and production grinders c topic for some students.

gestions for Student Activity	Discussion
L PROCESSES (A) (E) parison between the machining characteristics of tools, e.g., engine lathe vs. turrett lathe; shaper hine; vertical mill vs. horizontal mill. erimental study of cutting tool geometry as it re- cy. parison study between a multi-tooth and single tter. al removal with regard to: surface quality, size s, intricacy of shape, productivity.	The student may do a specific operation on three or four different machine tools as part of a major application assignment, e.g., a one two three block could be machined on a lathe, a mill and a shaper. Machining exercises could be used as a means of validating some of the research findings which relate to cutting tool geometry and single and multi-tooth cutters.
PPING AND HONING (A) of manufactured abrasives and their applications. r emphasis on aluminum oxide and silicon nding, lapping and honing as three methods of parts.	The student should be made aware of the increasing uses of abrasives even for basic machining operations. The increasing sophistication of toolroom and production grinders could form the basis of an interesting research topic for some students.

UNIT: 1.2 Manufacturing Me

Section	Topic	Element
12.2 Material removal (continued)	122.2 Special processes (O) (continued)	1222.2 Electrical discharge
		1222.3 Electrochemical
12.3 Material working	123.1 Forging 5	1231.1 Description of processes 1231.2 Types of forgings 1231.3 Properties of forgings 1231.4 Design considerations: parts and tooling 1231.5 Forging drawings

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UNIT: 1.2 Manufacturing Methods and Processes

Topic	Element	Cross-Reference	Technical Terms
Special processes (O) (continued)	1222.2 Electrical discharge	318.6	Cathode Anode Dielectric Capacitor Arc Ionized Cycle Microsecond Servosystem Silver tungsten Graphite Zinc alloys Electrode wear Erosion
	1222.3 Electrochemical	318.7 126.2	Electrolyte Insulation Conductor Corrosion Vat Amperes Diamond bonding
Forging	1231.1 Description of processes		Drop forging Cold impact Plastic deformation Grain direction Draft Flash Shrink Hot-work die steel
	1231.2 Types of forgings	1111.5	
	1231.3 Properties of forgings	1112.5	
	1231.4 Design considerations: parts and tooling	23.4	
	1231.5 Forging drawings	214.4	

Fundamentals	Suggestions for Student Activity	
Removal of metal by means of an electrical discharge between the tool and workpiece. Atomic and molecular structure	**ELECTRICAL DISCHARGE MACHINING (A)** • make a study of the impact of electrical discharge machining upon Canadian industry. • make a detailed study of a particular machining operation such as the production of a tungsten carbide die by this method.	Opportunities for observatio electrochemical machining s
A chipless metal removal operation using the electroplating principle. Molecular structure Chemical reaction	**ELECTROCHEMICAL MACHINING (A)** • compare electrochemical machining and electrical discharge machining.	
Plastic deformation and flow characteristics at optimum temperatures. Properties attributable to grain direction.	**MATERIAL WORKING (A)** • make an on-sight study of how a forged part is produced.	The use of audio-visual aids observation of various types upset forging and roll forgin process for the mass produc

ggestions for Student Activity	Discussion
ISCHARGE MACHINING (A) y of the impact of electrical discharge machining industry. ailed study of a particular machining operation roduction of a tungsten carbide die by this	Opportunities for observation by the students of electrical discharge and electrochemical machining should be arranged with local industry.
ICAL MACHINING (A) ctrochemical machining and electrical discharge	
RKING (A) sight study of how a forged part is produced.	The use of audio-visual aids combined with a plant tour which would permit observation of various types of forging such as drop forging, press forging, upset forging and roll forging will assist the student in understanding one process for the mass producing of tools and parts.

Section	Topic	Element
12.3 Material working (continued)	123.2 Extruding	1232.1 Descriptions of process 1232.2 Types 1232.3 Properties of extrusions 1232.4 Design considerations 1232.5 Extrusion drawings
	123.3 Stamping	1233.1 Description of processes: piercing, blanking 1233.2 Like processes: swaging, coining, embossings 1233.3 Design considerations
	123.4 Bending and forming	1234.1 Bend allowances 1234.2 Design considerations 1234.3 Cold roll forming 1234.4 Explosive forming 1234.5 Magnetic pulse
	123.5 Drawing	1235.1 Application to bar stock wire 1235.2 Application to drawn shells 1235.3 Design considerations

UNIT: 1.2 Manufacturing Methods and Processes

Topic	Element	Cross-Reference	Technical Terms
.2 Extruding	1232.1 Descriptions of process 1232.2 Types 1232.3 Properties of extrusions 1232.4 Design considerations 1232.5 Extrusion drawings	1111.5 1112.5 23.4 214.4	Hot, forward and indirect process Plunger, container, die, backer, dummy block Cold impact Die inserts Support rings
.3 Stamping	1233.1 Description of processes: piercing, blanking 1233.2 Like processes: swaging, coining, embossings 1233.3 Design considerations	1111.5 1112.5 23.4	Dies: progressive, drawing, blanking, compressive, forming, perforating, cutting, combination, shear, pressure, cold work, tool steels, clearance
.4 Bending and forming	1234.1 Bend allowances 1234.2 Design considerations 1234.3 Cold roll forming 1234.4 Explosive forming 1234.5 Magnetic pulse	1111.5 1112.5 23.4 1111.3	Bend allowance Fracture Velocity Stress Springback
.5 Drawing	1235.1 Application to bar stock wire 1235.2 Application to drawn shells 1235.3 Design considerations	1111.3 1111.5 1112.3 1112.5 23.4	Plastic deformation Draw dies Wrinkles Puckers Work hardening Mandrels Horizontal and circular draw benches Annealing Side wall and flange stresses Die cushion Double action, triple action

Fundamentals	Suggestions for Student Activity	Dis
Plastic deformation and flow characteristics under cold and hot pressure conditions.	**MANUFACTURING METHODS (A)** • examine various articles with regard to the merits of different manufacturing methods and processes: fabrication vs. casting sand mould vs. hard mould gravity vs. pressure casting extrusion vs. fabrication drawing vs. spinning forging vs. machining stamping vs. casting • make a study of mechanical properties resulting from a process such as: casting, machining, forging.	The interaction of part requireme be analyzed. The application of research ass column may be used in their e in size. The study of mechanical prope include how grain structure and s
Process of shear and plastic deformation under controlled conditions.		
Interaction of tensile and compressive stresses. Plastic deformation under controlled conditions.		
Interaction of stresses, work hardening and plastic deformation under controlled conditions of hot and cold work.		

estions for Student Activity	Discussion
G METHODS (A) s articles with regard to the merits of different thods and processes: sting rd mould essure casting brication inning achining sting f mechanical properties resulting from a process machining, forging.	The interaction of part requirements, volume and production costs, should be analyzed. The application of research assignments outlined in the student activity column may be used in their entirety or may be reduced considerably in size. The study of mechanical properties of a process could be expanded to include how grain structure and size is affected.

UNIT: 1.2 Manufacturing

Section	Topic	Element
12.3 Material working (continued)	**123.6 Spinning**	1236.1 Description of process 1236.2 Design considerations
12.4 Casting and moulding	**124.1 Gravity casting (sand)**	1241.1 Explanation of process 1241.2 Casting design features: sand, green and dry; metal and plaster moulds 1241.3 Applications
	124.2 Investment casting	1242.1 Explanation of process 1242.2 Design features 1242.3 Applications
	124.3 Pressure casting	1243.1 Die casting 1243.2 Centrifugal 1243.3 Applications
	124.4 Moulding of plastics	1244.1 Explanation of processes: compression, blow, transfer, injection, vacuum, jet, extrusion 1244.2 Applications
	124.5 Powdered metallurgy	1245.1 Explanation of process 1245.2 Applications

UNIT: 1.2 Manufacturing Methods and Processes

Topic	Element	Cross-Reference	Technical Terms
6 Spinning	1236.1 Description of process 1236.2 Design considerations	1111.5 1112.5 23.4	Centrifugal forces Centripetal forces
1 Gravity casting (sand)	1241.1 Explanation of process 1241.2 Casting design features: sand, green and dry; metal and plaster moulds 1241.3 Applications	11.1 214.4	Moulds, cores, patterns, core prints, core boxes, flasks, cope, drag, sprues, runners, feeders, gates, impression, risers Sands: green, dry, core, resin coated, bonders, Cupola, ladle Abrasive cleaning Shell casting
2 Investment casting	1242.1 Explanation of process 1242.2 Design features 1242.3 Applications	111.2	
3 Pressure casting	1243.1 Die casting 1243.2 Centrifugal 1243.3 Applications	111.2	Die casting Centrifugal
4 Moulding of plastics	1244.1 Explanation of processes: compression, blow, transfer, injection, vacuum, jet, extrusion 1244.2 Applications	112.1	Cavity Styrene, frozen mercury, slurry, injection Flash, dies, moulds Translucency Torpedo
5 Powdered metallurgy	1245.1 Explanation of process 1245.2 Applications	1221.4 3115.1	Briquette Compacting Sintering Sizing Bonding Porosity

Fundamentals	Suggestions for Student Activity	
Deformation of flat, rotating disc by controlled pressure to one side.	**SPINNING (A)** • write up an operations sheet.	
Solidification of a liquid metal into a predetermined shape.	**CASTING** • make a comparative study of gravity, investment and pressure casting processes.	The student may be given method of manufacture of considerations: Complexity of shape Volume requirements Size control Finish requirements Gate locations Scrap considerations Draft Strengths Colour Performance Assembly needs Appearance Manufacturing costs Number of operations Interchangeability Product Life
	PLASTIC • make a list of plastic parts and components which were originally made of metal. Consider all of the factors which would influence the change in material selection.	
Compression and fusion of metal granules into a predetermined shape.		

ggestions for Student Activity	Discussion
perations sheet.	
parative study of gravity, investment and pressure ses.	The student may be given a research project to determine the best method of manufacture of a proposed part based upon the following considerations: Complexity of shape Volume requirements Size control Finish requirements Gate locations Scrap considerations Draft Strengths Colour Performance Assembly needs Appearance Manufacturing costs Number of operations Interchangeability Product Life
of plastic parts and components which were origi- metal. Consider all of the factors which would hange in material selection.	

DIVISION 1: Core

UNIT: 1.2 Manufacturing

Section	Topic	Element
12.5 Fabrication	**125.1 Welding**	1251.1 Types of joints 1251.2 Processes 1251.3 Symbols 1251.4 Design considerations
	125.2 Riveting	1252.1 Type of rivets 1252.2 Symbols 1252.3 Application of rivets 1252.4 Rivet Loading
	125.3 Threaded fasteners	1253.1 Types 1253.2 Standard representation for particular applications
	125.4 Miscellaneous fasteners (O)	1254.1 Locking devices 1254.2 Insulated connectors
	125.5 Adhesives (O)	1255.1 Types 1255.2 Specific properties of each 1255.3 Applications

UNIT: 1.2 Manufacturing Methods and Processes

opic	Element	Cross-Reference	Technical Terms
elding	1251.1 Types of joints	214.5	M.I.G., T.I.G.
	1251.2 Processes	33.2	Submerged arc
	1251.3 Symbols		Embrittlement
	1251.4 Design considerations	23.4	C.S.A. and A.S.A. symbols
veting	1252.1 Type of rivets	3222.2	Bifurcated
	1252.2 Symbols		Hot and cold upsetting
	1252.3 Application of rivets		
	1252.4 Rivet Loading	214.1	
readed steners	1253.1 Types	214.1	Thread standards
	1253.2 Standard representation	3222.1	
	for particular applications	311.3	
scellaneous steners (O)	1254.1 Locking devices		Dielectric strength
	1254.2 Insulated connectors		Peel, cure
hesives (O)	1255.1 Types	112.2	Thermoplastic; polyamides
	1255.2 Specific properties of each		Thermosetting, epoxies,
	1255.3 Applications		phenolic-rubber

Fundamentals	Suggestions for Student Activity	D
Thermal fusion of metals.	**FABRICATION (A)** • examine various fabricated articles with regard to the advantages of: welding vs. riveting welding vs. threaded fasteners riveting vs. threaded fasteners as a means of joining parts. **FASTENERS (A)** • make a series of endurance tests regarding the various types of fasteners.	On sight observations by the s cesses will make this topic m disadvantages of various weldi Current trade literature such a mation on new types of fastene
Permanent fastening.		
Removable fastening.		
Adhesion.	**ADHESIVES (A)** • make a brief study of the use of adhesives as a fastening medium in the fabrication of various components.	

gestions for Student Activity	Discussion
(A) ous fabricated articles with regard to the advan- ting aded fasteners aded fasteners ining parts.) s of endurance tests regarding the various types	On sight observations by the students of modern production welding processes will make this topic much more meaningful. The advantages and disadvantages of various welding methods should receive basic coverage. Current trade literature such as machine design will have up-to-date information on new types of fasteners.
) study of the use of adhesives as a fastening abrication of various components.	

Section	Topic	Element
12.6 Surface coatings and finishes (O)	126.1 Mechanical and thermal diffusion	1261.1 Sprayed metal coatings; zinc, aluminum 1261.2 Vacuum metalizing; aluminum 1261.3 Organic coatings; paints, varnishes, lacquers, enamels, specialty finishes, vitreous enamel, plastics
	126.2 Electroplating	1262.1 Nickel, copper, chromium, cadmium, tin, silver, zinc, precious metals 1262.2 Electroforming
	126.3 Thermal and chemical coating	1263.1 Metallic cementation; aluminum, zinc, chromium, silicon 1263.2 Etch machining 1263.3 Oxide coating on ferrous metals 1263.4 Anodizing of aluminum, magnesium 1263.5 Hot dipped metal coating; iron, tin, lead, zinc 1263.6 Phosphate coatings; zinc, magnesium

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UNIT: 1.2 Manufacturing Methods and Processes

Topic	Element	Cross-Reference	Technical Terms
1 Mechanical and thermal diffusion	1261.1 Sprayed metal coatings; zinc, aluminum 1261.2 Vacuum metalizing; aluminum 1261.3 Organic coatings; paints, varnishes, lacquers, enamels, specialty finishes, vitreous enamel, plastics		Metalizing
2 Electroplating	1262.1 Nickel, copper, chromium, cadmium, tin, silver, zinc, precious metals 1262.2 Electroforming	1222.3 318.7	Electrode, cathode, anode Rectifier, Masking Deposition Mandrel
3 Thermal and chemical coating	1263.1 Metallic cementation; aluminum, zinc, chromium, silicon 1263.2 Etch machining 1263.3 Oxide coating on ferrous metals 1263.4 Anodizing of aluminum, magnesium 1263.5 Hot dipped metal coating; iron, tin, lead, zinc 1263.6 Phosphate coatings; zinc, magnesium		Alkaline Caustic Impregnation

Fundamentals	Suggestions for Student Activity	
Diffusion		The addition to a ba provide a coating to corrosive resistance
Ion flow	**ELECTROPLATING (E)** • set up an experiment whereby a particular metal is electrically "plated" with another metal.	The topics in this se tion and integration projects and researc
Chemical bonding	**THERMAL AND CHEMICAL COATING (A)** • make a list of common articles or parts which have been thermally or chemically coated. Describe the coating process. State why it was used.	

stions for Student Activity	Discussion
	The addition to a base material of a surface layer of another material to provide a coating to serve various purposes, e.g., appearance, durability, corrosive resistance is the subject material of this section.
(E) ment whereby a particular metal is electrically ner metal.	The topics in this section provide considerable material for close collaboration and integration with the science department of the school. Common projects and research assignments become a real possibility.
HEMICAL COATING (A) common articles or parts which have been ically coated. Describe the coating process. sed.	

Section	Topic	Element
12.7 Inspection	**127.1 Definition and purpose**	1271.1 Determining standards of quality 1271.2 Acceptable quality levels 1271.3 Standards and terms
	127.2 Tolerances	1272.1 Terminology 1272.2 Classes of fits 1272.3 Gauging systems
	127.3 Measuring practices	1273.1 Terminology 1273.2 Hardware 1273.3 Techniques

UNIT: 1.2 Manufacturing Methods and Processes

Topic	Element	Cross-Reference	Technical Terms
27.1 Definition and purpose	1271.1 Determining standards of quality 1271.2 Acceptable quality levels 1271.3 Standards and terms	3.3	Fixed comparative size Bilateral, unilateral Flats Chart gauge Oscilliscope
27.2 Tolerances	1272.1 Terminology 1272.2 Classes of fits 1272.3 Gauging systems	2115.1 33.1	Fits
27.3 Measuring practices	1273.1 Terminology 1273.2 Hardware 1273.3 Techniques	3124.6 33.1	Amplifiers: optical, mechanical, pneumatic, electronic Laser interferometer Ultrasonic tester Environmental testing

Fundamentals	Suggestions for Student Activity	
Quality control	**RESEARCH PROJECT ON INSPECTION (P)** • compile a report on inspection procedures and techniques used in local industries.	The assignment on inspecti individual research and repo orally, to the class. When all reports have been ment which may serve as a b
Classification (C)		
Amplification (C) Coherent Light		

Suggestions for Student Activity	Discussion
CH PROJECT ON INSPECTION (P) e a report on inspection procedures and techniques used ndustries.	The assignment on inspection procedures and techniques should involve individual research and reports. Each student could make his own report, orally, to the class. When all reports have been made, they may be collated into one document which may serve as a basis for a roundtable class discussion.

DIVISION 1: Core

UNIT: 1.3

Section	Topic	Element
13.1 Shafts and bearings	**131.1 Principles**	1311.1 Shafts, bearings 1311.2 Load conditions
	131.2 Shafts	1312.1 Purpose 1312.2 Types: rigid, flexible 1312.3 Design considerations 1312.4 Keys and splines 1312.5 Applications
	131.3 Sliding bearings	1313.1 Description 1313.2 Journal bearings 1313.3 Thrust bearings 1313.4 Design considerations 1313.5 Application
	131.4 Rolling contact bearings	1314.1 Description 1314.2 Commercial ball bearings; application 1314.3 Commercial roller bearings; application 1314.4 Design considerations

UNIT: 1.3 Transmission of Power

Topic	Element	Cross-Reference	Technical Terms
Principles	1311.1 Shafts, bearings 1311.2 Load conditions	127.2 214.3 221.4	Loads: Thrust, radial, combined shock
Shafts	1312.1 Purpose 1312.2 Types: rigid, flexible 1312.3 Design considerations 1312.4 Keys and splines 1312.5 Applications	3122.2 3171.3	Shaft — Woodruff key Key — Pratt & Whitney Spline
Sliding bearings	1313.1 Description 1313.2 Journal bearings 1313.3 Thrust bearings 1313.4 Design considerations 1313.5 Application	13.2	Journal
Rolling contact bearings	1314.1 Description 1314.2 Commercial ball bearings; application 1314.3 Commercial roller bearings; application 1314.4 Design considerations	13.2	Damping Pitting

Fundamentals	Suggestions for Student Activity	
Friction Torque, Stress: shear, torsion	**LOAD CONDITIONS (X)** • examine load conditions to which shafts are subjected.	The ease in assembling and d
	KEY AND SHAFT TYPES (A) • examine various types of keys and splines and determine the advantages and limitations of each. • examine shaft assemblies and their application. **KEY AND SHAFT DESIGN (X)** • select the most suitable key or spline sizes using available standard sizes. • calculate the correct diameter of shaft for a given load or torque. • determine a suitable hub diameter and length for a given shaft diameter.	Manufacturing methods fo explained. The importance of correct su lar application should be stre
	BEARING TYPES (A) • examine bearing assemblies in the school and their application in local industry. • compare sample sliding bearings and rolling contact bearings and determine the advantages and limitations of each.	Sealed rolling contact bear junction with lubrication in th
		The use of industrial catalo ever possible.

ggestions for Student Activity	Discussion
TIONS (X) d conditions to which shafts are subjected.	The ease in assembling and disassembling bearings and shafts is important.
AFT TYPES (A) rious types of keys and splines and determine the d limitations of each. ft assemblies and their application. **AFT DESIGN (X)** most suitable key or spline sizes using available s. e correct diameter of shaft for a given load or suitable hub diameter and length for a given shaft	Manufacturing methods for keyways, keyseats and splines should be explained. The importance of correct surface finish and shaft hardness for the particular application should be stressed.
ES (A) aring assemblies in the school and their application ry. mple sliding bearings and rolling contact bearings the advantages and limitations of each.	Sealed rolling contact bearings should be introduced particularly in conjunction with lubrication in the next topic.
	The use of industrial catalogues and charts should be encouraged whenever possible.

DIVISION 1: Core

UNIT: 1.3 T

Section	Topic	Element
13.1 Shafts and bearings (continued)	**131.4 Rolling contact bearings (continued)**	1314.4 Design considerations (continued)
13.2 Lubrication	**132.1 Fundamentals**	1321.1 Friction 1321.2 Perfect and imperfect lubrication 1321.3 Design considerations
	132.2 Fluid	1322.1 Oil classifications 1322.2 Synthetic

UNIT: 1.3 Transmission of Power

Topic	Element	Cross-Reference	Technical Terms
4 Rolling contact bearings (continued)	1314.4 Design considerations (continued)		
1 Fundamentals	1321.1 Friction	131.3	Viscosity
	1321.2 Perfect and imperfect lubrication	131.4	
	1321.3 Design considerations	2143.6	
2 Fluid	1322.1 Oil classifications	131.3	Centistroke
	1322.2 Synthetic	131.4	S.A.E., A.S.T.M., N.L.G.I. S.U.S.
		3131.5	

Fundamentals	Suggestions for Student Activity	
	BEARING SELECTION (X) • select the correct sliding and/or rolling contact bearing for a particular design problem. • determine the most suitable method of enclosing the bearing for a particular design problem.	
Reduction of friction and dissipation of heat. Viscosity	**LUBRICATION TYPES (A)** • compare the properties of various lubricants. **LUBRICATION SYSTEMS (A) (X)** • compare various lubrication systems and seals. • design a lubrication system.	Lubrication reduces friction housing. This section is closely rela bearings. The student should understar cants and how they are affecte Seals not only keep lubricant out. Shaft surface finish is o companies will have a techr the class. The use of technical catalogu lubrication devices should be
Synthesis (C)		

Suggestions for Student Activity	Discussion
SELECTION (X) the correct sliding and/or rolling contact bearing for a design problem. ine the most suitable method of enclosing the bearing cular design problem.	
TION TYPES (A) e the properties of various lubricants. **TION SYSTEMS (A) (X)** e various lubrication systems and seals. a lubrication system.	Lubrication reduces friction of a rotating or sliding body in a stationary housing. This section is closely related to the previous section on shafts and bearings. The student should understand the function of oil, grease and other lubricants and how they are affected by such variables as heat and speed. Seals not only keep lubricants in but also keep dust, dirt, and other fluids out. Shaft surface finish is of prime importance for many seals. Many oil companies will have a technical representative discuss lubrication with the class. The use of technical catalogues particularly for the selection of seals and lubrication devices should be encouraged.

Section	Topic	Element
13.2 Lubrication (continued)	**132.3 Grease and solids**	1323.1 Types of grease 1323.2 Solid lubricants
	132.4 Seals	1324.1 Purpose 1324.2 Design considerations 1324.3 Commercial types
	132.5 Systems (O)	1325.1 Journal bearings 1325.2 Gravity fed 1325.3 Pressure fed
13.3 Drive mechanisms	**133.1 Gearing**	1331.1 Purpose and principles 1331.2 Types 1331.3 Terminology 1331.4 Use of formulae 1331.5 Gear trains 1331.6 Design considerations 1331.7 Applications 1331.8 Manufacturing methods
	133.2 Cams	1332.1 Purpose and principles 1332.2 Types 1332.3 Motions 1332.4 Followers 1332.5 Terminology 1332.6 Displacement (time-motion) diagrams 1332.7 Design considerations 1332.8 Applications 1332.9 Manufacturing methods

UNIT: 1.3 Transmission of Power

Topic	Element	Cross-Reference	Technical Terms
rease and solids	1323.1 Types of grease 1323.2 Solid lubricants	131.3 131.4	Consistency Mechanical stability Bleeding rate Oxidation
eals	1324.1 Purpose 1324.2 Design considerations 1324.3 Commercial types	131.3 131.4	Circulating Oil jet Fittings
ystems (O)	1325.1 Journal bearings 1325.2 Gravity fed 1325.3 Pressure fed	2143.6	Oil bath Drop feed Wick feed Splash fed Slinger
earing	1331.1 Purpose and principles 1331.2 Types 1331.3 Terminology 1331.4 Use of formulae 1331.5 Gear trains 1331.6 Design considerations 1331.7 Applications 1331.8 Manufacturing methods	214.2 133.6 312.3	Gear, pinion, rack, idler Internal and external gears, spur, bevel, worm, spiral, helical. herringbone, hypoid Pressure angle Gear teeth: full, stub
Cams	1332.1 Purpose and principles 1332.2 Types 1332.3 Motions 1332.4 Followers 1332.5 Terminology 1332.6 Displacement (time-motion) diagrams 1332.7 Design considerations 1332.8 Applications 1332.9 Manufacturing methods	214.2 3123.4 318.3	Disc, face, cylindrical cams Uniform, modified uniform, harmonic and parabolic motions Base circle Displacement (throw), dwell Pressure angle Followers: pointed, flat, roller, positive return

Fundamentals	Suggestions for Student Activity	Disc
Chemical action		
Plasticity		
Systems approach		
The transfer of force and motion from one object to another by the use of toothed surfaces. Gear formulae	**GEAR DESIGN (X)** • design a spur gear. **GEAR ASSEMBLIES (A)** • examine gear assemblies and their application.	This topic should serve as a four drawing and making of gears. The student should be conversan knowledge of the more advanc material and manufacturing metho Gear catalogues may be used in th
The changing of rotary to reciprocating motion. Imparting a specific motion to a member by means of a cam and follower.	**CAM APPLICATIONS (A)** • examine cam and follower applications throughout school and industry. **CAM DESIGN (X)** • increase or decrease the pressure angle by changing base circle diameter or by offsetting the follower.	This topic will serve as a founda drawing and making of cams. A reciprocating motion can also as rack and pinion, pneumatics an

uggestions for Student Activity	Discussion
IGN (X) spur gear. **EMBLIES (A)** gear assemblies and their application.	This topic should serve as a foundation for other topics which cover the drawing and making of gears. The student should be conversant with basic gear types as well as have a knowledge of the more advanced types. The selection of the proper material and manufacturing methods should be discussed. Gear catalogues may be used in the solution of gearing problems.
ICATIONS (A) cam and follower applications throughout school and **GN (X)** or decrease the pressure angle by changing base circle or by offsetting the follower.	This topic will serve as a foundation for the other topics which cover the drawing and making of cams. A reciprocating motion can also be obtained by using such other methods as rack and pinion, pneumatics and hydraulics.

Section	Topic	Element
13.3 Drive mechanisms (continued)	**133.3 Couplings**	1333.1 Purpose and principles 1333.2 Types 1333.3 Design considerations 1333.4 Applications
	133.4 Clutches	1334.1 Purpose and principles 1334.2 Types 1334.3 Design considerations 1334.4 Applications
	133.5 Brakes	1335.1 Purpose and principles 1335.2 Types 1335.3 Design considerations 1335.4 Applications
	133.6 Flexible drives	1336.1 Purpose and principles 1336.2 Types 1336.3 Pulleys and sprockets 1336.4 Design considerations 1336.5 Applications
	133.7 Miscellaneous mechanisms (O)	1337.1 Direct contact drives 1337.2 Variable speed drives 1337.3 Intermittent motion mechanisms 1337.4 Linkages 1337.5 Power and transmission screws 1337.6 Differential mechanisms

UNIT: 1.3 Transmission of Power

Topic	Element	Cross-Reference	Technical Terms
ouplings	1333.1 Purpose and principles 1333.2 Types 1333.3 Design considerations 1333.4 Applications	2143.2	Flanged, shear pin Universal joint, floating centre, cushion
lutches	1334.1 Purpose and principles 1334.2 Types 1334.3 Design considerations 1334.4 Applications	2143.2	Positive, plate, and friction (conical, magnetic, centrifugal) clutches
rakes	1335.1 Purpose and principles 1335.2 Types 1335.3 Design considerations 1335.4 Applications	2143.2 22.1	Shoe, band, disc Electrical
exible drives	1336.1 Purpose and principles 1336.2 Types 1336.3 Pulleys and sprockets 1336.4 Design considerations 1336.5 Applications	133.1 2143.4	Wire rope Roller chain, ladder chain, block chain, Pitch, idler Pulley, sheave, crowned pulley sprocket
iscellaneous echanisms (O)	1337.1 Direct contact drives 1337.2 Variable speed drives 1337.3 Intermittent motion mechanisms 1337.4 Linkages 1337.5 Power and transmission screws 1337.6 Differential mechanisms	214.3 3181.3	Friction wheels Variable-pitch sheave, rolling-contact drives Ratchet, escapement, Geneva wheel, intermittent gearing Four-bar, parallel, rod, eccentric Plain screws: acme, modified square, and buttress threads Differential screw, compound screw

Fundamentals	Suggestions for Student Activity	Di
The permanent or semi-permanent joining of one device to another to transmit motion.	**COUPLING AND/OR CLUTCH DESIGN (X)** • design a simple flanged coupling and/or conical clutch.	The skilful use of trade literat will stimulate student interest and clutches specifically.
The transmission of power from one moving body to another, through an intermediate device which has variable characteristics.		The importance of selecting t friction and heat dissipation sh
Motion control. Friction	**BRAKE DESIGN (X)** • analyze a typical brake design. • design a simple shoe brake.	This topic closely relates to s gears and flexible drives have final selection difficult. Spee conjunction with spur gears ca and sprocket diameters can b print machine in the drafting flexible drive mechanism.
The transmission of power from one shaft to another by means of a flexible component.	**FLEXIBLE DRIVES (X)** • calculate speeds, pulley and sprocket diameters. • study flexible drives and their application.	Industrial catalogues should flexible drive accessories. The student may select a part tion of belt, chain or gear as th
Modification of motion	**MISCELLANEOUS MECHANISMS (A) (O)** • analyze various mechanisms, noting design features.	A number of simple and comp available from industrial supp mitting power. Many of these industrial catalogues.

Suggestions for Student Activity	Discussion
NG AND/OR CLUTCH DESIGN (X) a simple flanged coupling and/or conical clutch.	The skilful use of trade literature-catalogues, film strips and sound movies will stimulate student interest in drive mechanisms generally and coupling and clutches specifically. The importance of selecting the correct material and the consideration of friction and heat dissipation should be stressed.
DESIGN (X) e a typical brake design. a simple shoe brake.	
E DRIVES (X) ate speeds, pulley and sprocket diameters. flexible drives and their application.	This topic closely relates to spur gears. The student must appreciate that gears and flexible drives have specific features that often overlap and make final selection difficult. Speed calculations for this topic can be done in conjunction with spur gears calculations, hence similarities between pulley and sprocket diameters can be related to gear pitch diameters. The white print machine in the drafting room usually provides a good example of a flexible drive mechanism. Industrial catalogues should be used where possible in the selection of flexible drive accessories. The student may select a particular drive problem and justify the application of belt, chain or gear as the best type of drive for that application.
LANEOUS MECHANISMS (A) (O) ze various mechanisms, noting design features.	A number of simple and complex mechanisms have been designed or are available from industrial suppliers to perform specific functions in transmitting power. Many of these are shown in mechanical design texts and industrial catalogues.

DIVISION 1: Core

UNIT: 1.3

Section	Topic	Element
13.4 Fluid power	134.1 Basic principles	1341.1 Force and pressure 1341.2 Static head 1341.3 Pascal's Law 1341.4 Velocity head 1341.5 Friction head 1341.6 Continuity principle 1341.7 Units
	134.2 Pneumatics	1342.1 Air supply system 1342.2 Directional control of cylinders 1342.3 Speed control of cylinders 1342.4 Sequential operation 1342.5 Rotary motors 1342.6 Industrial circuits
	134.3 Hydraulics	1343.1 Hydraulic supply systems 1343.2 Directional control of cylinders 1343.3 Speed control of cylinders 1343.4 Sequential operation 1343.5 Rotary motion components 1343.6 Industrial circuits
	134.4 Fluidics (O)	1344.1 Basic devices 1344.2 Applications

UNIT: 1.3 Transmission of Power

Topic	Element	Cross-Reference	Technical Terms
asic principles	1341.1 Force and pressure	22.1	Compressibility
	1341.2 Static head	22.2	
	1341.3 Pascal's Law		Force multiplication
	1341.4 Velocity head		
	1341.5 Friction head	13.1	
	1341.6 Continuity principle		Viscosity
	1341.7 Units		Conservation of energy
neumatics	1342.1 Air supply system		Pneumatic
	1342.2 Directional control of cylinders	13.3	Solenoid-operated Pilot-operated
	1342.3 Speed control of cylinders		Two-way, three-way valves
	1342.4 Sequential operation	13.5	Compressor
	1342.5 Rotary motors	31.6	Regulator
	1342.6 Industrial circuits	214.11	Standard symbols
ydraulics	1343.1 Hydraulic supply systems		Hydraulic
	1343.2 Directional control of cylinders	13.3	Valves: pressure-relief, unloading
	1343.3 Speed control of cylinders	31.5	Intensifier
	1343.4 Sequential operation		Actuators
	1343.5 Rotary motion components	13.5	Rotary cylinders
	1343.6 Industrial circuits	214.11	
luidics (O)	1344.1 Basic devices		Power stream
	1344.2 Applications		Channels: main, control, output

Fundamentals	Suggestions for Student Activity	
Pascal's Law Conservation of energy $Q = A_1V_1 = A_2V_2$ Bernoulli Principle	**FORCE MULTIPLICATION (E)** • demonstrate Pascal's Law quantitatively by two interconnected cylinders of equal size. **FLUID HEADS (E)** • measure static, velocity and friction heads by means of an open reservoir, pressure gauges and hydraulic line.	In many manufacturing p equipped with fluid power c Applications of fluid power There appears to be a gre knowledge of hydraulics an
Regulation (C) Gas Laws $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ Sequencing (C)	**SCHOOL HOIST SYSTEM (A)** • investigate the complete pneumatic system from central compressor to school hoist. **BASIC PNEUMATIC CIRCUIT (E)** • build simple circuits from schematic diagrams to demonstrate direction, speed and sequence control.	
Systems (C) Amplification (C) Linear to angular conversion	**HYDRAULIC SYSTEM (A)** • analyze the hydraulic circuit on one or more hydraulically-operated machines. **BASIC HYDRAULIC CIRCUITS (E)** • build simple circuits from schematic diagrams to demonstrate direction, speed and sequence control.	If the school has an Industr could be carried on very Industrial Physics laborato power test panels to provid
Logic devices Coanda effect Switching (C)	**FLUIDIC DEVICES (E)** • study the operation of basic fluidic devices and note their typical industrial applications.	

stions for Student Activity	Discussion
ATION (E) scal's Law quantitatively by two interconnected size.) velocity and friction heads by means of an open e gauges and hydraulic line.	In many manufacturing plants over half the production machinery is equipped with fluid power devices. Applications of fluid power are increasing rapidly. There appears to be a great shortage of industrial personnel who have knowledge of hydraulics and pneumatics.
SYSTEM (A) complete pneumatic system from central com- oist. **C CIRCUIT (E)** cuits from schematic diagrams to demonstrate nd sequence control.	
EM (A) draulic circuit on one or more hydraulically- s. **C CIRCUITS (E)** cuits from schematic diagrams to demonstrate d sequence control.	If the school has an Industrial Physics laboratory, the study of this Section could be carried on very effectively using apparatus in that area. If no Industrial Physics laboratory is available, the school may acquire fluid power test panels to provide "hands-on" experience.
(E) ation of basic fluidic devices and note their pplications.	

DIVISION 1: Core

UNIT: 1.3

Section	Topic	Element
13.5 Electrical power	**135.1 Calculation**	1351.1 D.C. 1351.2 Single-phase 1351.3 Three-phase 1351.4 Efficiency
	135.2 Rotating machines	1352.1 Motor principle 1352.2 Motor types 1352.3 Electrical connections
	135.3 Transformers	1353.1 Principle 1353.2 Construction 1353.3 Applications
	135.4 Control systems	1354.1 Manual 1354.2 Magnetic starters 1354.3 Automatic 1354.4 Protection devices

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UNIT: 1.3 Transmission of Power

Topic	Element	Cross-Reference	Technical Terms
Calculation	1351.1 D.C. 1351.2 Single-phase 1351.3 Three-phase 1351.4 Efficiency	 1221.2	Watts, power, energy Phase: single, three Phase angle Cosine
Rotating machines	1352.1 Motor principle 1352.2 Motor types 1352.3 Electrical connections	1342.5 221.4	Torque, horsepower
ransformers	1353.1 Principle 1353.2 Construction 1353.3 Applications		Step-up, step-down Efficiency
Control systems	1354.1 Manual 1354.2 Magnetic starters 1354.3 Automatic 1354.4 Protection devices		Magnetic circuit Disconnect, contactor Circuit breaker Relays

Fundamentals	Suggestions for Student Activity	
$W = E I$ $W = E I \cos \theta$ $W = \sqrt{3} E I \cos \theta$ Phase relationships % eff'y $= \frac{\text{output power}}{\text{input power}} \times 100$	**ELECTRIC MOTORS (E)** - determine the efficiency of one or more electrical motors.	The experiment to deter the electrical laboratory. by the teacher. A wattmeter connected t will give a crude but inte electrical power and mec
Conversion of energy Horsepower = 746 watts		The motor principle can b
Electromagnetic induction $\frac{E_1}{E_2} = \frac{T_1}{T_2} = \frac{I_2}{I_1}$	**TRANSFORMERS (E)** - confirm the relationships among turns, voltages and currents using a simple transformer.	
Programming (C) Automation	**MOTOR CONNECTIONS (A)** - analyze the complete electrical circuit from supply lines through a magnetic starter and through the internal wiring of a three-phase induction motor.	The students should be a of motor control circuits.

uggestions for Student Activity	Discussion
OTORS (E) the efficiency of one or more electrical motors.	The experiment to determine motor efficiency can be done conveniently in the electrical laboratory. It should be performed, even if it must be set up by the teacher. A wattmeter connected to the input of a motor driving a lathe or drill press will give a crude but interesting demonstration of the relationship between electrical power and mechanical work.
	The motor principle can be easily demonstrated with simple equipment.
ERS (E) e relationships among turns, voltages and currents e transformer.	
NECTIONS (A) complete electrical circuit from supply lines through tarter and through the internal wiring of a three- on motor.	The students should be able to do simple trouble-shooting and maintenance of motor control circuits.

DIVISION 2: Drafting and Design

UNIT: 2.1 G

Section	Topic	Element
21.1 Basic Drawing	**211.1 Geometric Construction**	2111.1 Use of instruments, machines and facilities 2111.2 Review of earlier geometric constructions 2111.3 Ellipses 2111.4 Curves 2111.5 Spirals 2111.6 Helix
	211.2 Technical Sketching	2112.1 Proportions 2112.2 Shading techniques 2112.3 Perspective 2112.4 Pictorial aspects
	211.3 Elementary Projections	2113.1 First and third angle projections 2113.2 Alternate positions 2113.3 Partial views 2113.4 Normal, inclined and oblique edges and surfaces 2113.5 Curved and cylindrical surfaces 2113.6 Space curves 2113.7 Conventions
	211.4 Sectioning	2114.1 Review of full, half and offset sections 2114.2 Types of advanced sectioning, e.g., revolved, removed, broken out, phantom, etc. 2114.3 Conventions, Standard Breaks
	211.5 Dimensioning and Tolerances	2115.1 Review of earlier dimensioning techniques 2115.2 Dimensioning systems, e.g. co-ordinates, datums

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UNIT: 2.1 Graphic Representation

Element	Cross-Reference	Technical Terms
2111.1 Use of instruments, machines and facilities		Planes, plane figure Geometric solid Ellipses Involutes Archimedes spiral
2111.2 Review of earlier geometric constructions		
2111.3 Ellipses		
2111.4 Curves	212.1	
2111.5 Spirals	212.6	
2111.6 Helix	214.2	
2112.1 Proportions		Elevations Rendering Plan Contrasts Vanishing points Foreshortening
2112.2 Shading techniques	23.1	
2112.3 Perspective		
2112.4 Pictorial aspects		
2113.1 First and third angle projections		The six basic views Scale Alphabet of lines Orthographic CSA ASA
2113.2 Alternate positions		
2113.3 Partial views		
2113.4 Normal, inclined and oblique edges and surfaces		
2113.5 Curved and cylindrical surfaces		
2113.6 Space curves		
2113.7 Conventions		
2114.1 Review of full, half and offset sections	211.6	Cutting plane line Sectioning symbols
2114.2 Types of advanced sectioning, e.g., revolved, removed, broken out, phantom, etc.		
2114.3 Conventions, Standard Breaks	13.1	
2115.1 Review of earlier dimensioning techniques	1272.1 1272.2	Bilateral Unilateral Basic hole and shaft Gaugemaker's tolerance Work tolerance zone Microinch Waviness, lay, roughness
2115.2 Dimensioning systems, e.g. co-ordinates, datums	3222.3 31.6 3162.2	

Fundamentals	Suggestions for Student Activity	Dis
True relationships between lines and surfaces.	**GEOMETRIC DRAWINGS (P)** • make drawings involving geometric principles, such as hexagons and curves.	The use of illustrated reference t of geometric forms and construc
Graphic communication Creativity	**SKETCHING (P)** • sketch industrial components.	Technical sketching should rec start on a sketch pad".
Aspects of shape, surfaces and edges in communication.	**ELEMENTARY PROJECTIONS (P)** • make drawings of industrial components.	Elementary projections should before proceeding to advanced p
Aspects of interior shapes, surfaces and edges to improve communication.	**SECTIONING (P)** • make sectional views.	Opportunities for the study of factured products should be mad drawing techniques can be stud could be undertaken.
Aspect of size and location in communication. Tolerance (C)	**DIMENSIONING** • make drawings of assemblies and details to develop bills of materials, revision schedules, weight and cost sheets. • Compute tolerances.	

tions for Student Activity	Discussion
INGS (P) involving geometric principles, such as s.	The use of illustrated reference texts will help to emphasize the importance of geometric forms and constructions.
components.	Technical sketching should receive special emphasis since "all designs start on a sketch pad".
ECTIONS (P) industrial components.	Elementary projections should be thoroughly understood by the student before proceeding to advanced projections.
ews.	Opportunities for the study of working drawings which illustrate manufactured products should be made available to the students so that current drawing techniques can be studied in detail. Individual or group studies could be undertaken.
f assemblies and details to develop bills of chedules, weight and cost sheets. es.	

Section	Topic	Element
21.1 Basic Drawing (continued)	211.6 Working Drawings	2116.1 Detail 2116.2 Assembly 2116.3 Bills of materials 2116.4 Revisions and checking 2116.5 Weight, cost and specification sheets
	211.7 Reproduction of Drawings	2117.1 Dry process 2117.2 Wet process 2117.3 Photographic processes
21.2 Advanced Projection Systems	212.1 Auxiliary Views	2121.1 Selection of direction of sight 2121.2 Selection of reference plane 2121.3 Classification of auxiliary view
	212.2 Revolutions (O)	2122.1 Axis perpendicular to the frontal plane 2122.2 Axis perpendicular to the profile plane 2122.3 Successive revolutions
	212.3 Axonometric Projection (O)	2123.1 Isometric projection and dimensioning 2123.2 Isometric assemblies (exploded) 2123.3 Dimetric projection and dimensioning 2123.4 Trimetric projection and dimensioning
	212.4 Oblique Projection	2124.1 Selection of axis 2124.2 Choice of position 2124.3 Oblique projection and dimensioning

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UNIT: 2.1 Graphic Representation

Topic	Element	Cross-Reference	Technical Terms
orking Drawings	2116.1 Detail		RMS Allowance Limits Notes
	2116.2 Assembly		
	2116.3 Bills of materials		
	2116.4 Revisions and checking	211.4	
	2116.5 Weight, cost and specification sheets	12.1	
eproduction of rawings	2117.1 Dry process		Light sensitive Developing Enlargement, reduction Microfilm, microfiche Sepia intermediates
	2117.2 Wet process		
	2117.3 Photographic processes		
uxiliary Views	2121.1 Selection of direction of sight	211.6	Direction of sight Primary and secondary views
	2121.2 Selection of reference plane	2111.3	
	2121.3 Classification of auxiliary view		
evolutions (O)	2122.1 Axis perpendicular to the frontal plane		Axes Successive revolutions
	2122.2 Axis perpendicular to the profile plane		
	2122.3 Successive revolutions		
xonometric ojection (O)	2123.1 Isometric projection and dimensioning	121.3	Isometric scales and drawings Offset measurements Box construction Non-isometric line
	2123.2 Isometric assemblies (exploded)	2111.3	
	2123.3 Dimetric projection and dimensioning		
	2123.4 Trimetric projection and dimensioning		
blique ojection	2124.1 Selection of axis		Cabinet Cavalier
	2124.2 Choice of position	121.3	
	2124.3 Oblique projection and dimensioning		

Fundamentals	Suggestions for Student Activity	Discuss
The addition of necessary information for the production of components.	**WORKING DRAWINGS (P) (X)** • make drawings of assemblies and details to develop bills of materials, revision schedules, weight and cost sheets.	Student production of detail and as closely as possible to student activity i
Chemical action.	**REPRODUCTION (A)** • use school reproduction machines. • explore industrial applications.	Some students may wish to make a stu being used in industry.
Alternate views for clarity of communication.	**AUXILIARY VIEWS (P)** • make drawings of industrial components with oblique surfaces which require auxiliary views and/or revolution of the object.	The pictorial topics, although interes pleasant aesthetic rewards, can be sketching and assigned for homework. The use of reference texts and c emphasized.
Alternate positions for clarity of communication.		
Pictorial representation, in which the axes are variable.	**PICTORIAL PROJECTION (P)** • make drawings of industrial components using pictorial projection systems. The drawings may include single view, isometric sections, exploded sections, exploded assemblies and dimensioning.	
Pictorial representation in which the receding axis is drawn at an angle.		

Suggestions for Student Activity	Discussion
NG DRAWINGS (P) (X) drawings of assemblies and details to develop bills of s, revision schedules, weight and cost sheets.	Student production of detail and assembly drawings should relate as closely as possible to student activity in the machine shop.
UCTION (A) chool reproduction machines. e industrial applications.	Some students may wish to make a study of current reproduction methods being used in industry.
RY VIEWS (P) drawings of industrial components with oblique surfaces quire auxiliary views and/or revolution of the object.	The pictorial topics, although interesting to the student and producing pleasant aesthetic rewards, can be reduced in time if combined with sketching and assigned for homework. The use of reference texts and current trade literature should be emphasized.
AL PROJECTION (P) drawings of industrial components using pictorial projec- tems. The drawings may include single view, isometric , exploded sections, exploded assemblies and dimen-	

DIVISION 2: Drafting and Design

UNIT: 2.1 G

Section	Topic	Element
21.2 Advanced Projection Systems (continued)	212.5 Perspective Projection (O)	2125.1 Selection of perspective type 2125.2 Selection of vanishing points, horizon line 2125.3 Projection techniques
	212.6 Intersections and Developments	2126.1 Intersections of geometric forms 2126.2 Development of surfaces
21.3 Technical Charts and Graphs	213.1 Types of Graphs and Charts	2131.1 Principle of graphical representation 2131.2 Plotting of lines, curves and bars 2131.3 Scales and proportions
	213.2 Engineering Graphics	2132.1 Principle of charting mathematical proportions 2132.2 Scales and conversions 2132.3 Types, e.g., nomograph, vectors algebraic
21.4 Industrial practices	214.1 Drafting Office Routine	2141.1 Division of responsibility 2141.2 Office systems, e.g., reproduction, filing, routing

Design

UNIT: 2.1 Graphic Representation

Topic	Element	Cross-Reference	Technical Terms
2.5 Perspective Projection (O)	2125.1 Selection of perspective type 2125.2 Selection of vanishing points, horizon line 2125.3 Projection techniques	121.3	Picture plane Ground line Vanishing point Point of sight (station point)
2.6 Intersections and Developments	2126.1 Intersections of geometric forms 2126.2 Development of surfaces	211.1	Solid surface classifications Development intersection Parallel, radial and triangulation procedures Lock seams Sheet metal gauges Galvanize Duct work nomenclature
3.1 Types of Graphs and Charts	2131.1 Principle of graphical representation 2131.2 Plotting of lines, curves and bars 2131.3 Scales and proportions	121.3	Critical path Log scales Abscissa Ordinate Grids
3.2 Engineering Graphics	2132.1 Principle of charting mathematical proportions 2132.2 Scales and conversions 2132.3 Types, e.g., nomograph, vectors algebraic	331.3 221.3	Bar Sector Scale designations Empirical Symbols
4.1 Drafting Office Routine	2141.1 Division of responsibility 2141.2 Office systems, e.g., reproduction, filing, routing	211.7	Blue-print, White Print, Photocopy, Micro-film, Electrostatic, Mimeographing, Heat Sensitive

Fundamentals	Suggestions for Student Activity	Di
Pictorial representation in which the receding axes converge on vanishing points.	**PERSPECTIVE (P)** • make drawings of industrial components using the pictorial projection systems.	
Plotting of planes of intersection. Unfolding of a surface to a plane.	**INTERSECTIONS (D)** • make drawings of component parts involving intersections and developments of sheet metal parts. • Cardboard models may be made.	
Tabulation of data for analysis. Graphical representation of data.	**GRAPHS (P)** • make drawings and/or sketches of various types of graphs utilizing industrial type problems or data.	Various methods of charting an to other topics for applications ment can assist greatly. More graphs is the ability to understa
	TRANSLUCENT MEDIUMS (P) (E) (A) • make drawings on various translucent mediums, e.g., vellum, nylon, linen and produce copies using various processes.	

Suggestions for Student Activity	Discussion
VE (P) awings of industrial components using the pictorial systems.	
IONS (D) awings of component parts involving intersections and nts of sheet metal parts. rd models may be made.	
P) awings and/or sketches of various types of graphs dustrial type problems or data.	Various methods of charting and making graphs should be explained. Relate to other topics for applications. By preplanning the mathematics department can assist greatly. More important than making various charts and graphs is the ability to understand them.
ENT MEDIUMS (P) (E) (A) awings on various translucent mediums, e.g., vellum, n and produce copies using various processes.	

DIVISION 2: Drafting and Design

UNIT: 2.1 G

Section	Topic	Element
21.4 Industrial practices (continued)	**214.2 Structural**	2142.1 Material types and properties 2142.2 Standard shapes and abbreviations 2142.3 Joint types and applications 2142.4 Calculations
	214.3 Electrical and Electronic (O)	2143.1 Symbols 2143.2 Circuits 2143.3 Layout practices
	214.4 Casting and Forging	2144.1 Manufacturing methods 2144.2 Accuracy, shape, quantity, shrink and draft considerations 2144.3 Current methods of representation
	214.5 Threads Fasteners and Springs	2145.1 Definition of terms 2145.2 Thread forms and uses 2145.3 Representation, CSA Standard Symbols, detailed methods 2145.4 Screw thread calculations 2145.5 Fastener types, specifications, use and standard representation 2145.6 Spring types and uses 2145.7 Spring calculations

UNIT: 2.1 Graphic Representation

	Element	Cross-Reference	Technical Terms
.2	2142.1 Material types and properties 2142.2 Standard shapes and abbreviations 2142.3 Joint types and applications 2142.4 Calculations	22.1 22.2 1111.6 1112.6	CSA/ASA standards AISC standard shapes ASA standard shapes Hot rolled, masonry Extruded Fabricated Laminated Riveted, welded, bolted and fused joints Column, joist, truss, beam type structures Shear, deflection, moments Tensile, compression Cantilever, loads Reinforcement, stress level, gauge line ACI Standards
.3 Electrical and Electronics (D)	2143.1 Symbols 2143.2 Circuits 2143.3 Layout practices	13.5	CSA/ASA Symbols Series, Parallel and Combination Circuits Schematic, Line Drawings Schedules, Block Diagrams
.4 Casting and Forging	2144.1 Manufacturing methods 2144.2 Accuracy, shape, quantity, shrink and draft considerations 2144.3 Current methods of representation	12.4	Sand, Permanent, Investment, Precision and Die Casting Drop, High Velocity, Draft, Shrink, Parting Line, Tolerances, Hot Spots, Fillets, Ribs, Bosses, Residual Stress, Coring
.5 Threads Fasteners and Springs	2145.1 Definition of terms 2145.2 Thread forms and uses 2145.3 Representation, CSA Standard Symbols, detailed methods 2145.4 Screw thread calculations 2145.5 Fastener types, specifications, use and standard representation 2145.6 Spring types and uses 2145.7 Spring calculations	125.2 125.3 311.3 1312.4 3122.2	Removable fasteners Permanent fasteners Spring nomenclature Screw thread nomenclature Keyway, keyseat

Fundamentals	Suggestions for Student Activity	
Construction principles for structures. Various formulae to establish strengths, loads.	**STRUCTURAL DESIGN (P) (X)** • make drawings and/or sketches of structural members which involve both design and calculation. • make a fabrication schedule.	Structural drafting and as as cranes and other heav emphasis of the course.
Schematic representation.	**CIRCUIT DIAGRAMS (P) (A)** • make drawings and/or sketches of circuit diagrams with schedules which cover both electrical and electronic representation.	
Mass production.	**CASTINGS AND FORGINGS (P) (X) (E)** • make drawings of both castings and forgings which will require consideration of design practices, including weight, strength and production factors.	
	FASTENERS (P) • make drawings of industrial components utilizing the simplified CSA standards. • make selection and representation of commercial fasteners, springs and keys.	The topic of fasteners sh standard hardware lists a Simplified drawing meth

uggestions for Student Activity	Discussion
L DESIGN (P) (X) vings and/or sketches of structural members which design and calculation. rication schedule.	Structural drafting and assignments related to industrial applications such as cranes and other heavy equipment items will maintain the mechanical emphasis of the course.
AGRAMS (P) (A) wings and/or sketches of circuit diagrams with hich cover both electrical and electronic represen-	
AND FORGINGS (P) (X) (E) vings of both castings and forgings which will require n of design practices, including weight, strength on factors.	
(P) vings of industrial components utilizing the simplified ds. ection and representation of commercial fasteners, keys.	The topic of fasteners should incorporate the use of tables, table drawings, standard hardware lists and loading graphs. Simplified drawing methods should be discussed.

DIVISION 2: Drafting and Design

UNIT: 2.1 G

Section	Topic	Element
21.4 Industrial Practices (continued)	214.6 Gears and Cams	2146.1 Gear types and uses 2146.2 Terminology and calculations 2146.3 Methods of representation 2146.4 Cam types and related mechanisms and uses 2146.5 Terminology, diagrams and calculations 2146.6 Methods of representation
	214.7 Mechanisms	2147.1 Linkages, actuators, related motion and uses 2147.2 Clutches, couplings, braking devices and uses 2147.3 Clamping and fastening devices and applications 2147.4 Drives, i.e. belt, cone, chain, hydraulic, pneumatic 2147.5 Bearing types and applications 2147.6 Lubrication, calculations and graphic representation for all mechanisms listed
	214.8 Tool Drawings	2148.1 Tooling types and applications 2148.2 Terminology and calculations and selections of materials 2148.3 Current representation practices

UNIT: 2.1 Graphic Representation

Topic	Element	Cross-Reference	Technical Terms
Gears and Cams	2146.1 Gear types and uses 2146.2 Terminology and calculations 2146.3 Methods of representation 2146.4 Cam types and related mechanisms and uses 2146.5 Terminology, diagrams and calculations 2146.6 Methods of representation	133.1 312.3 133.2 3123.4 3171.2 318.3	Spur types (internal, external, rack) Angular types (bevel) Helical types (worm, hypoid spiral) Involute (generated profile) Backlash Disc cam Face cam Cylindrical cam Yoke Follower Displacement
Mechanisms	2147.1 Linkages, actuators, related motion and uses 2147.2 Clutches, couplings, braking devices and uses 2147.3 Clamping and fastening devices and applications 2147.4 Drives, i.e. belt, cone, chain, hydraulic, pneumatic 2147.5 Bearing types and applications 2147.6 Lubrication, calculations and graphic representation for all mechanisms listed	133.3 133.4 133.5 133.6 13.1 13.2	Amplification Friction drive Positive drive Variable drive Sleeve, ball, roller Viscosity, emulsion, consistency, dissipation
Tool Drawings	2148.1 Tooling types and applications 2148.2 Terminology and calculations and selections of materials 2148.3 Current representation practices	12.3 3163.1 22.2	Jig and fixture nomenclature Die and punch press nomenclature Mould nomenclature Gauge nomenclature A.I.S.I., S.A.E., (tool steel)

Fundamentals	Suggestions for Student Activity	D
Transmission of force and motion. Ratios.	**GEARS AND CAMS (P)** • make drawings of various types of gears, cams, mechanisms, bearings and clutches using industrial type problems involving transmission of power.	Gear catalogues should be method of gear drawing will s cams within the school should
Transmission of motion to produce intermittent, reciprocating, reversing, adjusting, torque limiting, governing and counting movement.	**MECHANISMS (P)** • make a drawing of a simple mechanism. • take field trip within/without the school, e.g., Centennial Centre of Science and Technology.	Charts and graphs can again b Simple design problems and u interest in mechanisms. The student-led round table discu
	TOOL DRAWINGS (P) • make drawings of tooling necessary to produce industrial parts, e.g., drill jig, milling fixture, pierce and blank die.	The topic of tool drawings pr duction of product design. A in the drafting room and produ

iggestions for Student Activity	Discussion
CAMS (P) vings of various types of gears, cams, mechanisms, -clutches using industrial type problems involving of power.	Gear catalogues should be used at every opportunity. The simplified method of gear drawing will save much time. The application of gears and cams within the school should be exploited to reinforce this topic.
S (P) wing of a simple mechanism. rip within/without the school, e.g., Centennial Centre d Technology.	Charts and graphs can again be utilized. Simple design problems and use of the "sketch pad" should help to arouse interest in mechanisms. The use of working models as a focal point for student-led round table discussion will stimulate interest.
INGS (P) ings of tooling necessary to produce industrial parts, milling fixture, pierce and blank die.	The topic of tool drawings provides an excellent opportunity for the introduction of product design. A simple jig, fixture or die could be designed in the drafting room and produced in the machine shop.

Section	Topic	Element
21.4 Industrial Practices (continued)	214.9 Welding	2149.1 Processes 2149.2 Types of joints and welds 2149.3 Symbols and representation
	214.10 Piping (O)	214.10.1 Pipe, fittings and joint types 214.10.2 Valve types and applications 214.10.3 Calculations 214.10.4 Current representation practices
	214.11 Fluid power (O)	214.11.1 Symbols 214.11.2 Circuits 214.11.3 Layout practices
	214.12 Technological innovations (O)	214.12.1 Systems: graphic display, computer plotter, data reduction, photogrammetry 214.12.2 Data processing 214.12.3 Techniques: transfer, photographic

10.8

UNIT: 2.1 Graphic Representation

Topic	Element	Cross-Reference	Technical Terms
4.9 Welding	2149.1 Processes 2149.2 Types of joints and welds 2149.3 Symbols and representation	125.1	Arc, gas, resistance, M.I.G. T.I.G.. bead, fillet, plug, groove, projection, spot, seam, flash Submerged arc Electrode Flux CSA/ASA symbols Butt, lap, tee, corner and edge type joints
4.10 Piping (O)	214.10.1 Pipe, fittings and joint types 214.10.2 Valve types and applications 214.10.3 Calculations 214.10.4 Current representation practices	13.4	ASA schedule/code Flanged, soldered and fused joints Velocity Gate, globe, check Remote, solenoid, pilot Controls, schematic, double line pictorial
4.11 Fluid power (O)	214.11.1 Symbols 214.11.2 Circuits 214.11.3 Layout practices	134.2 134.3	Pneumatic Hydraulic Valves: pilot, two-way three-way, four-way
4.12 Technological innovations (O)	214.12.1 Systems: graphic display, computer plotter, data reduction, photogrammetry 214.12.2 Data processing 214.12.3 Techniques: transfer, photographic	2117.3	Computer plotter Photogrammetry

Fundamentals	Suggestions for Student Activity	Dis
Fusion fabrication Symbolism	**TOOL DRAWINGS (P)** • make drawings of fabricated industrial components which require joint and process selection.	A brief survey of recent innovat cluded when presenting this topi
Schematic representation	**PIPING SYSTEMS (P)** • make drawings and/or sketches of closed piping systems involving design and calculations.	Rough sketches of various parts a basis for detail drawings. The optional topic of piping can is used as an aid; student drawin be compared with architects draw
Energy conversion	**INNOVATIVE SYSTEMS (P)** • draw and analyse block diagrams of typical innovation systems.	
Systems (C) Information: storage handling Memory (C) Polarization		If a numerical control machine i for simple machining operations.

Suggestions for Student Activity	Discussion
RAWINGS (P) drawings of fabricated industrial components which re- nt and process selection.	A brief survey of recent innovations in welding techniques should be included when presenting this topic.
SYSTEMS (P) drawings and/or sketches of closed piping systems in- design and calculations.	Rough sketches of various parts of the school plumbing could be used as a basis for detail drawings. The optional topic of piping can be most interesting if the "school plant" is used as an aid; student drawings made from exploration sketches could be compared with architects drawings.
ATIVE SYSTEMS (P) and analyse block diagrams of typical innovation systems.	
	If a numerical control machine is available students might produce tapes for simple machining operations.

DIVISION 2: Drafting and Design

UNIT:

Section	Topic	Element
22.1 Forces	221.1 Description of a force	2211.1 Characteristics 2211.2 Effects 2211.3 Units
	221.2 Types	2212.1 Non-contact 2212.2 Contact 2212.3 Combined
	221.3 Vector analysis	2213.1 Force representation 2213.2 Vector quantity 2213.3 Combination of vectors
	221.4 Turning effects	2214.1 Moment of a force 2214.2 Sum of the moments about a point
	221.5 Equilibrium of forces	2215.1 Free body diagrams 2215.2 Conditions for equilibrium

UNIT: 2.2 Applied Mechanics

Topic	Element	Cross-Reference	Technical Terms
Description of a force	2211.1 Characteristics 2211.2 Effects 2211.3 Units		Force units: pounds, tons
Types	2212.1 Non-contact	22.2	Scalar quantity
	2212.2 Contact	134.1	
	2212.3 Combined		
Vector analysis	2213.1 Force representation 2213.2 Vector quantity		Forces: gravitational, magnetic, electric, muscular, tension compression, shear, bending, torsion, friction
	2213.3 Combination of vectors	1351.3	
Turning effects	2214.1 Moment of a force	1311.2	Torque
	2214.2 Sum of the moments about a point	214.6	Couple Centre of gravity
Equilibrium of forces	2215.1 Free body diagrams		Space diagram
	2215.2 Conditions for equilibrium	222.4	Point of contact of a force Reaction forces

Fundamentals	Suggestions for Student Activity	D
A force has a magnitude and direction. A force is exerted by one body on another. An unbalanced force will cause a body to accelerate.		
Force field concept		
Graphically a force may be represented by a vector. Vectors can be added to determine a resultant.		
M = Moment = Force x $\perp$ distance Rotational Equilibrium $\Sigma M = 0$	**FORCE ANALYSIS (E)** • analyze both qualitatively and quantitatively torque wrench action on a bolt.	
Graphical analysis in two dimensions of all forces on a body. Translational Equilibrium: Σ Vertical Forces $= 0$ Σ Horizontal Forces $= 0$	**SPACE AND FORCE DIAGRAMS** • draw free body force diagrams of simply loaded links or trusses pinned at one point. Determine graphically the magnitude and direction of the pin reaction force.	The concept of a perpendic surfaces can be reinforced in

gestions for Student Activity	**Discussion**
SIS (E) qualitatively and quantitatively torque wrench	
ORCE DIAGRAMS dy force diagrams of simply loaded links or trusses point. Determine graphically the magnitude and pin reaction force.	The concept of a perpendicular reaction at roller-supported or smooth surfaces can be reinforced in this exercise.

DIVISION 2: Drafting and Design UNIT:

Section	Topic	Element
22.2 Statics	222.1 Tensile force (O)	2221.1 Deflection 2221.2 Strain 2221.3 Stress 2221.4 Young's Modulus
	222.2 Compressive force	2222.1 Deflection 2222.2 Strain 2222.3 Stress 2222.4 Young's Modulus
	222.3 Shear force	2223.1 Deflection 2223.2 Strain 2223.3 Stress 2223.4 Modulus of rigidity
	222.4 Bending moments	2224.1 Deflection of a beam 2224.2 Force-deflection relationships 2224.3 Bending stress 2224.4 Shear force and bending moment diagrams
	222.5 Twisting moments (O)	2225.1 Deflection 2225.2 Strain 2225.3 Stress
	222.6 Failure under load	2226.1 Static loads 2226.2 Dynamic loads 2226.3 Repetitive loads

UNIT: 2.2 Applied Mechanics

Topic	Element	Cross-Reference	Technical Terms
Tensile force (O)	2221.1 Deflection 2221.2 Strain 2221.3 Stress 2221.4 Young's Modulus	332.2 214.7 221.1	Deflection Proportional limit Yield point Deformation: longitudinal, lateral
Compressive force	2222.1 Deflection 2222.2 Strain 2222.3 Stress 2222.4 Young's Modulus	332.2 134.1 214.5 214.6	Unit strain Normal stress Young's Modulus (E)
Shear force	2223.1 Deflection 2223.2 Strain 2223.3 Stress 2223.4 Modulus of rigidity	332.2 131.1 133.3 214.5 311.1 31.4 315.2	Shear strain Shear stress Modulus of rigidity (G)
Bending moments	2224.1 Deflection of a beam 2224.2 Force-deflection relationships 2224.3 Bending stress 2224.4 Shear force and bending moment diagrams	221.5	Moment of Inertia (I) Bending Moment (M) Distance from neutral axis (C) Diagrams: shear force, bending moments
Twisting moments (O)	2225.1 Deflection 2225.2 Strain 2225.3 Stress	332.2 131.1	Angle of twist θ Radians Torque (T)
Failure under load	2226.1 Static loads 2226.2 Dynamic loads 2226.3 Repetitive loads	332.2	Yield point Ultimate strength Loads: uniform, point Failure Fatigue

Fundamentals	Suggestions for Student Activity	Di
Hooke's Law Linearity Elasticity unit strain = $\frac{\text{total deformation}}{\text{original length}}$ unit stress = $\frac{\text{perpendicular load}}{\text{cross-sectional area}}$ E = $\frac{\text{unit stress}}{\text{unit strain}}$ Deformation is parallel to force	**HOOKE'S LAW (E)** • investigate the range of Hooke's Law by loading a spring and steel wire in tension beyond their elastic limit. Graph results. • graph stress-strain relation for a spring under compression.	This whole Section can be treat on self-discovery of the beha elements associated with sever If the school has an Industria equipment from it should be us Industrial Physics laboratory i test apparatus for experiment should not be limited to "chalk-
$G = \frac{\text{unit shear stress}}{\text{unit shear strain}}$	**SHEAR TEST (E)** • investigate shear on riveted or bolted plates, using tensile tester. • demonstrate shear in sheet metal by punch action, using a compression cage.	
Beam deflection = $K\frac{WL^3}{EI}$ Stress = $\frac{MC}{I}$	**BENDING TEST (E)** • measure and graph, load vs. deflection, on cantilevered and two end supported length of strap iron.	Deflection of a beam depends o
$\theta = KT$ (Hooke's Law)	**TORSION TEST (E)** • graph torque vs. angular deflection on torsion test device.	
Static vs. dynamic Fatigue	**DESTRUCTIVE TESTS (E)** • perform destructive tests on various materials and classify type of failure.	

ggestions for Student Activity	Discussion
V (E) the range of Hooke's Law by loading a spring and ension beyond their elastic limit. Graph results. -strain relation for a spring under compression.	This whole Section can be treated as a long experiment with the emphasis on self-discovery of the behaviour of materials. Note the similarity of elements associated with several topics. If the school has an Industrial Physics laboratory, the materials testing equipment from it should be used to provide "hands-on" experience. If no Industrial Physics laboratory is available, the school may acquire some test apparatus for experiments in this Section. The study of the topics should not be limited to "chalk-and-talk" activity.
(E) shear on riveted or bolted plates, using tensile shear in sheet metal by punch action, using a age.	
T (E) d graph, load vs. deflection, on cantilevered and two length of strap iron.	Deflection of a beam depends on at least four factors.
T (E) e vs. angular deflection on torsion test device.	
TESTS (E) structive tests on various materials and classify	

DIVISION 2: Drafting and Design

UNIT

Section	Topic	Element
23.1 Design Considerations	**231.1 Aesthetic Features**	2311.1 Styling 2311.2 Social acceptance
	231.2 Functional Features	2312.1 Mechanical strength 2312.2 Dynamic stability 2312.3 Reliability of performance 2312.4 Material suitability 2312.5 Production feasibility 2312.6 Economic feasibility

UNIT: 2.3 Design Evaluation

Topic	Element	Cross-Reference	Technical Terms
1 Aesthetic Features	2311.1 Styling 2311.2 Social acceptance	23.4 211.2	Aesthetic Functional
2 Functional Features	2312.1 Mechanical strength 2312.2 Dynamic stability 2312.3 Reliability of performance 2312.4 Material suitability 2312.5 Production feasibility 2312.6 Economic feasibility	11.1 11.2 2.2 121.3 	Independent Variables Production Volume Surface finish Control required Geometry Materials and hardness Fuels and lubricants Precision Pressures and concentrations Dependent Variables (on above) Life Weight Corrosion resistance Strength Efficiency Capacity Cost Wear resistance Rigidity Safety Speed

Fundamentals	Suggestions for Student Activity	
Discrimination (C) Perception (C) Aesthetic principles		Aesthetic principles of des
Synthesis of many variables	**MACHINE DESIGN (P)** • design a simple machine.	

Suggestions for Student Activity	Discussion
	Aesthetic principles of design include the following: form, texture, color.
DESIGN (P) a simple machine.	

Section	Topic	Element
23.2 Manufacturing Considerations	**232.1 Available manufacturing methods and processes**	2321.1 Existing or additional facilities 2321.2 Methods analysis 2321.3 Process analysis 2321.4 Schedule requirements 2321.5 Plant layout 2321.6 Service requirements
	232.2 Selection of Materials	2322.1 Mechanical properties 2322.2 Make-or-buy decisions 2322.3 Availability
	232.3 Costs	2323.1 Quantity required 2323.2 Utilization of standards 2323.3 Cost estimating — materials to market 2323.4 Prime labour costs 2323.5 Overhead factors 2323.6 Tooling and equipment costs 2323.7 Amortization 2323.8 Product revisions

UNIT: 2.3 Design Evaluation

Topic	Element	Cross-Reference	Technical Terms
32.1 Available manufacturing methods and processes	2321.1 Existing or additional facilities	12.1	
	2321.2 Methods analysis		
	2321.3 Process analysis		
	2321.4 Schedule requirements		
	2321.5 Plant layout		
	2321.6 Service requirements		
32.2 Selection of Materials	2322.1 Mechanical properties	11.1 11.2	
	2322.2 Make-or-buy decisions	2.2	
	2322.3 Availability		
32.3 Costs	2323.1 Quantity required	121.3	Costing
	2323.2 Utilization of standards	121.4	
	2323.3 Cost estimating — materials to market	23.1	
	2323.4 Prime labour costs		
	2323.5 Overhead factors		
	2323.6 Tooling and equipment costs		Amortization
	2323.7 Amortization		
	2323.8 Product revisions		

Fundamentals	Suggestions for Student Activity	
Analysis (C)	**MANUFACTURING (P) (A)** • develop a complete plan for a manufactured product. Include symbols and flow chart. Use a simple 4 or 5 step operation which can be performed in the school.	The need for layout plan cussed.
Economic utilization of facilities and materials Selectivity (C)	• write specifications for quality control requirements to insure that a product meets design requirements.	
Costing Estimating (C)	• make a cost study to estimate the final cost of a product.	Capital investment neede should be examined.

Suggestions for Student Activity	Discussion
CTURING (P) (A) a complete plan for a manufactured product. Include nd flow chart. Use a simple 4 or 5 step operation which formed in the school.	The need for layout planning and various flow diagrams should be discussed.
ecifications for quality control requirements to insure uct meets design requirements.	
cost study to estimate the final cost of a product.	Capital investment needed, operating costs, material and labour costs should be examined.

Section	Topic	Element
23.3 Quality Assurance	**233.1 Relationship to Design**	2331.1 Designing effectiveness into a product
	233.2 Quality Control	2332.1 Definition 2332.2 Total quality control concept 2332.3 Organization 2332.4 Elimination of defects 2332.5 Setting standards 2332.6 Drawing control system 2332.7 Measuring conformance
23.4 Creative Design Problems		

UNIT: 2.3 Design Evaluation

Topic	Element	Cross-Reference	Technical Terms
Relationship to Design	2331.1 Designing effectiveness into a product	23.2 12.7	Tolerance Specification
Quality Control	2332.1 Definition		Random inspection Prototype Line sample Drawing depository Zero defects program Instrument standard
	2332.2 Total quality control concept		
	2332.3 Organization	12.1	
	2332.4 Elimination of defects		
	2332.5 Setting standards	211.5	
	2332.6 Drawing control system	33.1	
	2332.7 Measuring conformance		

Fundamentals	Suggestions for Student Activity	D
Recognition and treatment of product abilities through identification, measurement, specification, control and improvement.		Give a general outline of th formance to ensure that part
Specification of performance and dependability within the allowance cost.	**QUALITY CONTROL (P)** • set up quality control group organization to ensure the quality of the product. • set up inspection and test stations. • specify a sampling plan.	The philosophy of quality co tion should be discussed.
	DESIGN PROBLEMS (P) • solve technological problems which integrate knowledge and skills from all divisions of the course.	Student activity suggestions imagination and resourcefuln

ggestions for Student Activity	Discussion
	Give a general outline of the necessity of establishing standards of performance to ensure that parts and products produced will be usable.
NTROL (P) lity control group organization to ensure the quality t. ection and test stations. ampling plan.	The philosophy of quality control as a part of the manufacturing organization should be discussed.
BLEMS (P) nological problems which integrate knowledge and divisions of the course.	Student activity suggestions for this section have been left entirely to the imagination and resourcefulness of the teacher.

DIVISION 3: Machine Theory and Practice

UNIT: 3.1

Section	Topic	Element
31.1 Lathe	**311.1 Turning**	3111.1 Parallel turning 3111.2 Facing 3111.3 Taper turning 3111.4 Form turning 3111.5 Eccentric turning 3111.6 Cutting feeds and speeds
	311.2 Hole production	3112.1 Cutting speeds and feeds 3112.2 Drilling 3112.3 Boring 3112.4 Reaming
	311.3 Threading	3113.1 Standard threads 3113.2 Multiple start threads
	311.4 Work holding devices	3114.1 Chucks 3114.2 Face plates 3114.3 Steady and follower rests 3114.4 Fixtures
	311.5 Cutting tools and tool holding devices	3115.1 Materials and types of cutting tools 3115.2 Turret tool post 3115.3 Turret tailstock attachement

UNIT: 3.1 Machining Operations

Topic	Element	Cross-Reference	Technical Terms
Turning	3111.1 Parallel turning 3111.2 Facing 3111.3 Taper turning 3111.4 Form turning 3111.5 Eccentric turning 3111.6 Cutting feeds and speeds	122.1	Grooving Throw Shear
Hole production	3112.1 Cutting speeds and feeds 3112.2 Drilling 3112.3 Boring 3112.4 Reaming	122.1	Boring bar Taper sleeves Machine reamer
Threading	3113.1 Standard threads 3113.2 Multiple start threads	125.3 214.1	Double start Double pitch Lead Helix Indexing
Work holding devices	3114.1 Chucks 3114.2 Face plates 3114.3 Steady and follower rests 3114.4 Fixtures		Collet chuck
Cutting tools and tool holding devices	3115.1 Materials and types of cutting tools 3115.2 Turret tool post 3115.3 Turret tailstock attachement	113.1 124.5	Cutting tools: facing, radius, chamfering, knurling, grooving, parting turning tools, tool holder

Fundamentals	Suggestions for Student Activity	
Material removal, usually from a revolving workpiece by a cutting tool. Cutting tool geometry. Cutting speeds for various metals. $R.P.M. = \frac{4\ CS}{D}$ $T.P.F. = \frac{(LD - SD) \times 12}{TL}$ $T.O. = \frac{TPF \times OL}{12 \times 2}$	**SPINDLE SPEEDS (X)** • given any combination of cutting tool, material and machine condition, students will calculate a desirable spindle speed. **TAPER TURNING (X)** • given T.P.F., included angle, or the three dimensions of any tapered shank, students will calculate tailstock offset or attachment guide bar setting. **PARALLEL, 90° TO AXIS, & TAPERED SURFACES (ME)** • turn a blank for a tapered shank drill.	The screw-cutting engine These experiences may c diameter and length, the the machining of highly-a of any desired form, lead a
	CONCENTRIC, ROUND, ACCURATE HOLES (ME) • turn a parallel bearing bushing to standard tolerances.	
Development of a helix	**NATIONAL FORM & ACME THREADS (ME)** • set up and cut any 60° or acme form thread to fit a standard gauge nut. **MULTIPLE START THREADS (ME)** • cut a multiple start thread. • cut an internal national form thread with a single point tool.	
The holding of a workpiece, rigidly, accurately and without distortion.	**MOUNTING THE WORKPIECE (ME)** • set up, bore and thread a shaft larger than the lathe spindle hole. **TURRET DEVICES (ME) (A)** • turn a parallel drill jig bushing. • observe turret-type and multiple spindle automatics.	Given any workpiece withi and auxiliary equipment, t spindle so that the operat be met. As with other more adva carefully organized plant t
Selectivity (C)		

uggestions for Student Activity	**Discussion**
EDS (X) combination of cutting tool, material and machine dents will calculate a desirable spindle speed. **ING (X)** ., included angle, or the three dimensions of any , students will calculate tailstock offset or attach- r setting. **0° TO AXIS, & TAPERED SURFACES (ME)** for a tapered shank drill.	The screw-cutting engine lathe should continue to play a vital role. These experiences may cover the accurate sizing of parallel cylinders in diameter and length, the production of standard and non-standard tapers, the machining of highly-accurate holes and the cutting of screw threads of any desired form, lead and number of starts.
. ROUND, ACCURATE HOLES (ME) lel bearing bushing to standard tolerances.	
ORM & ACME THREADS (ME) cut any 60° or acme form thread to fit a standard **ART THREADS (ME)** le start thread. nal national form thread with a single point tool.	
HE WORKPIECE (ME) e and thread a shaft larger than the lathe spindle **CES (ME) (A)** lel drill jig bushing. ret-type and multiple spindle automatics.	Given any workpiece within the machining capacity of the available lathes and auxiliary equipment, the student will be able to set it up on the lathe spindle so that the operation will be safe and all required tolerances will be met. As with other more advanced applications of the basic machine tools, carefully organized plant trips will provide invaluable experience.

DIVISION 3: Machine Theory and Practice

UNIT: 3.1

Section	Topic	Element
31.2 Milling machine	**312.1 Standard milling operations**	3121.1 Peripheral milling 3121.2 Face milling 3121.3 Side milling 3121.4 End milling 3121.5 Fly cutting 3121.6 Sawing and slitting 3121.7 Cutting speeds and feeds for the milling machine
	312.2 Form milling operations	3122.1 Gang and straddle milling 3122.2 Tee slots and keyways 3122.3 Dovetails 3122.4 Contour cutting
	312.3 Indexing operations	3123.1 Indexing 3123.2 Cutting of gear teeth

UNIT: 3.1 Machining Operations

Topic	Element	Cross-Reference	Technical Terms
Standard milling operations	3121.1 Peripheral milling 3121.2 Face milling 3121.3 Side milling 3121.4 End milling 3121.5 Fly cutting 3121.6 Sawing and slitting 3121.7 Cutting speeds and feeds for the milling machine	122.1	Collet Helix Staggered-tooth Shell and mill Inserted tooth Fly cutter Rake; positive, zero, negative Radial relief Climb milling Cutting speed Chip load
Form milling operations	3122.1 Gang and straddle milling 3122.2 Tee slots and keyways 3122.3 Dovetails 3122.4 Contour cutting	131.2 3171.4	Gang milling
Indexing operations	3123.1 Indexing	133.1 214.2 3172.3	Dividing head: footstock plates, sector arms, differential
	3123.2 Cutting of gear teeth	133.1 214.2	Gearing terms Cutter number

Fundamentals	**Suggestions for Student Activity**	
Cutting tool geometry. Production of external and internal surfaces in horizontal, vertical or angular attitudes using single or multi-tooth rotating cutters. R.P.M. $= \frac{4\,CS}{D}$ Feed rate = cutter R.P.M. x chip load x No. of teeth	**GENERATION OF PLANE SURFACES IN THREE ATTITUDES (ME)** • mill a step block. • mill all surfaces of a drill press vise body. • mill a V block. **CUTTER R.P.M. & FEED RATE (X) (E)** • calculate spindle R.P.M. and desirable feed rate given all data. **MACHINING TIME (X) (E)** • calculate machining time.	The shop equipment sh lash nut on the table fee Production of a finishe Emphasis should be pla cutting actions of cu geometric accuracy time required for the relative merits of cu The inductive methods the electrical circuitry tive observations of cu negative and positive materials and type of c
Production of multi-plane and/or curved surfaces by specially-shaped single cutters or by a combination of cutters.	**SURFACE FINISH CHARACTERISTICS (E)** • investigate and compare results of conventional and climb milling. **HOLDING DEVICES (A) (E)** • examine commercial milling fixtures and experiment with rigidity of holding devices as a function of the feeding method. **T SLOTS, KEYWAYS, DOVETAILS (ME)** • set up and mill shaped slots using shank-driven formed cutters.	
Indexing (C)	**INDEXING (X)** • calculate for rapid, plain, angular and differential indexing. **INVOLUTE SPUR GEARS AND RACKS (ME)** • mill the rack and pinion for a small arbour press. **WORM GEARING (ME) (A)** • gash and hob a worm gear. • examine a commercial application of a worm and worm wheel with regard to: materials used; advantages and disadvantages. **COOLANTS (E)** • investigate: surface finish and cutter life as a function of coolant type and coolant flow.	Basic formulae for eac through inductive reas observation of the divid

Suggestions for Student Activity	Discussion
ATION OF PLANE SURFACES **EE ATTITUDES (ME)** a step block. all surfaces of a drill press vise body. a V block. **R R.P.M. & FEED RATE (X) (E)** ulate spindle R.P.M. and desirable feed rate given all data. **INING TIME (X) (E)** ulate machining time.	The shop equipment should include one machine fitted with an anti-backlash nut on the table feed screw. Production of a finished "product" must never be the prime consideration. Emphasis should be placed on comparing and contrasting: cutting actions of cutter types geometric accuracy and quality of surface produced. time required for the removal of one cubic inch of material. relative merits of cutter mounting and driving devices. The inductive methods would be enhanced by connecting a wattmeter to the electrical circuitry of the milling machine. This would allow comparative observations of cutting efficiency when changes in R.P.M.; chip load, negative and positive rake, tooth clearance, number of teeth, types of materials and type of coolant are made.
CE FINISH CHARACTERISTICS (E) stigate and compare results of conventional and climb . **NG DEVICES (A) (E)** nine commercial milling fixtures and experiment with of holding devices as a function of the feeding method. **TS, KEYWAYS, DOVETAILS (ME)** p and mill shaped slots using shank-driven formed cutters.	
NG (X) ulate for rapid, plain, angular and differential indexing. **UTE SPUR GEARS AND RACKS (ME)** the rack and pinion for a small arbour press. **GEARING (ME) (A)** and hob a worm gear. nine a commercial application of a worm and worm wheel egard to: materials used; advantages and disadvantages. **ANTS (E)** stigate: surface finish and cutter life as a function of t type and coolant flow.	Basic formulae for each of the four indexing methods can be developed through inductive reasoning from data derived through manipulation and observation of the dividing head and attachments.

DIVISION 3: Machine Theory and Practice

UNIT: 3.

Section	Topic	Element
31.2 Milling machine (continued)	**312.3 Indexing operations (continued)**	3123.3 Helical milling 3123.4 Cam milling 3123.5 Rotary table milling
	312.4 Attachments (O)	3124.1 Vertical head 3124.2 Universal head 3124.3 Slotting attachment 3124.4 Rotary head 3124.5 Indicators and end measures 3124.6 Optical measuring devices 3124.7 Duplicating devices 3124.8 Tape controlled devices

UNIT: 3.1 Machining Operations

Topic	Element	Cross-Reference	Technical Terms
3 Indexing operations (continued)	3123.3 Helical milling	2111.6	
	3123.4 Cam milling	133.2	Cam Linear motion Reciprocating motion Dwell Uniform cam rise Harmonic motion Parabolic motion Cam types: uniform rise, radial, face, scroll, drum, beam type
	3123.5 Rotary table milling		
4 Attachments (O)	3124.1 Vertical head		End measures Die sinking Digital readout Dovetail
	3124.2 Universal head		
	3124.3 Slotting attachment	3171.1	
	3124.4 Rotary head		
	3124.5 Indicators and end measures		
	3124.6 Optical measuring devices	127.3	
	3124.7 Duplicating devices	3313.8	
	3124.8 Tape controlled devices	318.5	

Fundamentals	Suggestions for Student Activity	
Generation of a helix Generation of a cam Kinds of motion	**HELICAL GROOVES (E) (ME)** • set up one-to-one gearing between dividing head and table feed. Establish the machine "lead". • mill a simulated ten-tooth cutter. Consider the use of aluminum or hardwood as a gear blank. **CAMS (ME) (X)** • calculate, set up and mill a uniform rise cam. **MOULDS (ME)** • mill a cavity for a small ashtray or coaster (thermosetting material).	Some students may wel and production methods and reamers. The study o observation would make students. A student may wish to assignment which would production or trace briefl
Metrology Reproduction (C)	**ATTACHMENTS (A)** • make an application study of any one of the devices listed in the elements column.	These attachments great can be done on the millin Production of flat, circu geometries, both internal

Suggestions for Student Activity	Discussion
L GROOVES (E) (ME) p one-to-one gearing between dividing head and table feed. h the machine "lead". simulated ten-tooth cutter. Consider the use of aluminum wood as a gear blank. **(ME) (X)** late, set up and mill a uniform rise cam. **S (ME)** a cavity for a small ashtray or coaster (thermosetting l).	Some students may welcome a research assignment on the applications and production methods of helical milled products such as gears, drills and reamers. The study of current trade literature combined with industrial observation would make this type of assignment very challenging for some students. A student may wish to combine the machining of a cam with a written assignment which would outline machining difficulties encountered in cam production or trace briefly the many and varied types and uses of cams.
MENTS (A) an application study of any one of the devices listed in the s column.	These attachments greatly increase the range of machining tasks which can be done on the milling machine. Production of flat, circular, angular, or a combination of these surface geometries, both internal and external, can be performed more easily.

DIVISION 3: Machine Theory and Practice

UNIT: 3

Section	Topic	Element
31.3 Drilling machines	313.1 Operations	3131.1 Cutting speeds and feeds 3131.2 Drilling 3131.3 Countersinking 3131.4 Counterboring and spot facing 3131.5 Cutting fluids 3131.6 Jigs
	313.2 Hole finishing	3132.1 Reaming 3132.2 Burnishing 3132.3 Tapping
31.4 Sawing and filing machines	314.1 Sawblade selection	3141.1 Types of sawblades 3141.2 Factors determining selection 3141.3 Welding a sawblade
	314.2 Sawing	3142.1 Cut-off 3142.2 Contour 3142.3 Friction
	314.3 Filing	3143.1 Plain surfaces 3143.2 Contours 3143.3 Angles

UNIT: 3.1 Machining Operations

Topic	Element	Cross-Reference	Technical Terms
Operations	3131.1 Cutting speeds and feeds 3131.2 Drilling 3131.3 Countersinking 3131.4 Counterboring and spot facing 3131.5 Cutting fluids 3131.6 Jigs	122.1 1322.2	Radial drill Gang drill Multi-spindle drill Turret-head drill press Jig
Hole finishing	3132.1 Reaming 3132.2 Burnishing 3132.3 Tapping		
Sawblade selection	3141.1 Types of sawblades 3141.2 Factors determining selection 3141.3 Welding a sawblade	122.1	Standard tooth Skip tooth Straight set Raker set Wavy set Kerf
Sawing	3142.1 Cut-off 3142.2 Contour 3142.3 Friction		Contour Friction
Filing	3143.1 Plain surfaces 3143.2 Contours 3143.3 Angles		Bandfile

Fundamentals	Suggestions for Student Activity	
The production of round holes by means of a revolving cutting tool, cutting speed and field formulae.	**HOLE PRODUCTION & FINISHING OPERATIONS (ME) (X) (E) (A)** • calculate R.P.M. • drill to an accurate location. • countersink, counterbore, spotface. **APPLICATION OF CUTTING FLUIDS (E) (A)** • evaluate cutting fluids with regard to: Tool life, reduction of heat, surface finish, cost.	
Finishing (C)	**REAM A HOLE (ME)** **TAP A HOLE ON DRILL PRESS (ME)** **FIELD TRIP (A)** • visit an automated production line.	
Hardness	**SAWING & FILING OPERATIONS (ME) (A)** • weld a saw blade. • cut an irregular pattern • friction saw • band file a surface • field study the manufacture • files	The student should materials. Contour sawing sho Friction sawing will of a variety of resou Band filing equipme able to select the fil
Shear		

Suggestions for Student Activity	Discussion
RODUCTION & FINISHING OPERATIONS **) (E) (A)** ate R.P.M. an accurate location. ersink, counterbore, spotface. **TION OF CUTTING FLUIDS (E) (A)** te cutting fluids with regard to: , reduction of heat, surface finish, cost.	
HOLE (ME) **HOLE ON DRILL PRESS (ME)** **RIP (A)** n automated production line.	
& FILING OPERATIONS (ME) (A) a saw blade. irregular pattern n saw ile a surface tudy the manufacture	The student should know how to select a saw blade for different types of materials. Contour sawing should be undertaken even as a machining exercise. Friction sawing will most likely be a discussion topic. The need therefore of a variety of resource material for this topic becomes imperative. Band filing equipment can be added to a bandsaw. The student should be able to select the file desired and proceed to file a flat surface.

Section	Topic	Element
31.5 Grinding and precision finishing	**315.1 Work-holding devices**	3151.1 Magnetic devices 3151.2 Multi-angle vises 3151.3 Sine plate and angle plates 3151.4 Clamping devices
	315.2 Grinding wheels	3152.1 Grinding wheel identification 3152.2 Truing and dressing
	315.3 Standard grinding operations	3153.1 Offhand grinding 3153.2 Surface grinding 3153.3 Cylindrical grinding 3153.4 Form grinding and thread grinding 3153.5 Jig grinding (O) 3153.6 Tool and cutter grinding

UNIT: 3.1 Machining Operations

Topic	Element	Cross-Reference	Technical Terms
1 Work-holding devices	3151.1 Magnetic devices 3151.2 Multi-angle vises 3151.3 Sine plate and angle plates 3151.4 Clamping devices	1222.1 3312.2	Magnetic chuck, parallels and vee block Sine bar Gauge blocks Parallel clamps Fixtures
2 Grinding wheels	3152.1 Grinding wheel identification 3152.2 Truing and dressing	1222.1	Abrasive, aluminum oxide, silicon carbide, loading, glazing, truing, dressing, structure, grain, bond, vitrified, crush forming, blotters.
3 Standard grinding operations	3153.1 Offhand grinding 3153.2 Surface grinding 3153.3 Cylindrical grinding 3153.4 Form grinding and thread grinding 3153.5 Jig grinding (O) 3153.6 Tool and cutter grinding	1222.1 134.3	Peripheral speed S.F.P.M., R.P.M. Burning, checking, Chatter, deburring Plunge, internal & external grinding Tooth rest Primary & secondary clearance Land Regulating wheel Work rest blade Wheel speed, work speed Crush form grinding

Fundamentals	Suggestions for Student Activity	D
The holding of a work-piece, rigidly, accurately and without distortion. Trigonometric ratios	**ANGLE PLATE (ME) (P)** • clamp a parallel to an angle plate at a given angle.	The various methods of holding given to the different requirem a milling operation should be s the magnetic devices work a magnetic and non-magnetic de
Shearing action. Arrangement of abrasives to provide optimum cutting conditions.	**GRINDING WHEELS (ME)** • dress a grinding wheel.	Point out that for every grind suited for the operation. The s selection.
Metal removal by the cutting action of abrasives. Cutting tool geometry. S.F.P.M. = $\frac{RPM \times D}{4}$	**OFFHAND GRINDING (ME)** • grind a toolbit. **SURFACE GRINDING (P)** • perform various operations. **CYLINDRICAL GRINDING (ME)** • grind a lathe centre. **TOOL AND CUTTER GRINDING (ME)** • grind a milling cutter.	The importance of ideal conditi during all grinding operations s Items such as wheel and wo and selection of grinding whe samples of poorly ground work suggest ways by which it cou suggestion and put it into pract

Suggestions for Student Activity	Discussion
TE (ME) (P) arallel to an angle plate at a given angle.	The various methods of holding work should be explored. Special emphasis given to the different requirements of a grinding operation as opposed to a milling operation should be stressed. Explain the principles upon which the magnetic devices work and the relative holding power of various magnetic and non-magnetic devices.
WHEELS (ME) inding wheel.	Point out that for every grinding operation there is a wheel that is best suited for the operation. The student should be capable of making a logical selection.
GRINDING (ME) olbit. **RINDING (P)** arious operations. **AL GRINDING (ME)** he centre. **CUTTER GRINDING (ME)** lling cutter.	The importance of ideal conditions if satisfactory results are to be obtained during all grinding operations should be stressed. Items such as wheel and work speeds; choice of work holding devices and selection of grinding wheels must be carefully considered. Obtain samples of poorly ground work and have students identify the problem and suggest ways by which it could have been avoided. If possible take their suggestion and put it into practice by means of a demonstration.

DIVISION 3: Machine Theory and Practice

UNIT: 3.1

Section	Topic	Element
31.5 Grinding and precision finishing (continued)	315.4 Super-finishing (O)	3154.1 Honing 3154.2 Lapping
31.6 Jig boring	316.1 Introduction	3161.1 Description and purpose of a jig borer 3161.2 Principle of operation and importance of accuracy
	316.2 Operation	3162.1 Setting up the workpiece 3162.2 Establishing a reference point 3162.3 Moving from reference points to first hole location 3162.4 Machining a hole 3162.5 Types of cutting tools and adaptors
	316.3 Applications	3163.1 Toolmaking 3163.2 Inspection
31.7 Shaping, planing and slotting	317.1 Operations	3171.1 Shaping horizontal, vertical, angular, contoured surfaces 3171.2 Cutting keyways 3171.3 Cutting keyseats 3171.4 Shaping dovetails 3171.5 Serrating

and Practice

UNIT: 3.1 Machining Operations

Topic	Element	Cross-Reference	Technical Terms
uper-finishing O)	3154.1 Honing 3154.2 Lapping	1222.1 3313.6	Surface finish Charged hones Lapping compound
troduction	3161.1 Description and purpose of a jig borer 3161.2 Principle of operation and importance of accuracy	2115.2 134.2	Rectangular coordinates X and Y Polar coordinates Woodworth tables
peration	3162.1 Setting up the workpiece 3162.2 Establishing a reference point 3162.3 Moving from reference points to first hole location 3162.4 Machining a hole 3162.5 Types of cutting tools and adaptors	2115.2	Distortion, deflection Warping, twisting Shims Edge finder, dial indicator Wiggler, microscope
pplications	3163.1 Toolmaking 3163.2 Inspection	214.4	Optics Gauges: taper leaf, hole telescopic
perations	3171.1 Shaping horizontal, vertical, angular, contoured surfaces 3171.2 Cutting keyways 3171.3 Cutting keyseats 3171.4 Shaping dovetails 3171.5 Serrating	3124.3 3122.3	Planer gauge

Fundamentals	Suggestions for Student Activity	
Finishing (C)	**HONING (ME)** • hone a bushing	If project warrants, hav bell-mouthing problem if necessary.
The accurate positioning and sizing of holes by means of X and Y co-ordinates.	**JIG BORING (ME)** • accurately locate and bore 2 holes.	The student should app of mass production me The vertical mill can graduated collars will accuracy can be obtair can be clamped on the distances between th indicator. Stress the importance its relationship to nu Reports on the local us tion tool.
Reference points Metrology		
Man as a toolmaker.		
The production of surfaces by the linear movement of the cutting tool or work-piece. Speed of Shaper Ram = $\frac{CS \times 7}{L}$ Where CS = Cutting Speed in feet per min. and L = Length of stroke	**HORIZONTAL AND VERTICAL SURFACES (ME)** • Machine a planeHorizontal and Vertical surface. **ANGULAR SURFACES** • machine an angular surface. **CONTOURED SURFACES** • machine a contoured surface **KEYWAYS (ME)** • machine a keyway. **SERRATING** • serrate a flat surface.	The following machine t Crank shaper Hydraulic shaper Gear shaper Hydraulic planer The Shaper affords exce Changing circular to Ratchet and pawl mo Differential speeds

Suggestions for Student Activity	Discussion
(ME) ushing	If project warrants, have student hone a bushing to suit a pin. Point out bell-mouthing problem. The honing machine in the Auto shop can be used if necessary.
G (ME) ly locate and bore 2 holes.	The student should appreciate the role of the jig borer in the development of mass production methods. The vertical mill can be used. If measuring rods are not available, the graduated collars will do. Depending on the method, varying degrees of accuracy can be obtained. If time is limited, a plate with numerous holes can be clamped on the mill. Students can then check and record the centre distances between the holes using only the graduated collars and an indicator. Stress the importance of jig boring in toolmaking and inspection. Point out its relationship to numerical control. Have students prepare Research Reports on the local use of the jig borer both as a toolmaking and an inspection tool.
AL AND VERTICAL SURFACES (ME) a planeHorizontal and Vertical surface. **SURFACES** an angular surface. **ED SURFACES** a contoured surface **(ME)** a keyway. **G** a flat surface.	The following machine types should be mentioned: Crank shaper Hydraulic shaper Gear shaper Hydraulic planer Gear-Driven planer Double-Column planer Open-side planer The Shaper affords excellent opportunities to teach the following: Changing circular to reciprocating motion Ratchet and pawl motion Differential speeds

Section	Topic	Element
31.7 Shaping, planing and slotting (continued)	317.2 Work-holding devices	3172.1 Vises 3172.2 Table mounting and clamping devices 3172.3 Index centres
31.8 Special processes	318.1 Tracers	3181.1 Contour turning on the lathe 3181.2 Contour milling on vertical mill 3181.3 Pantograph
	318.2 Turret lathe	3182.1 Types 3182.2 Purpose 3182.3 Description
	318.3 Screw machines (O)	3183.1 Types 3183.2 Purpose 3183.3 Description

UNIT: 3.1 Machining Operations

Topic	Element	Cross-Reference	Technical Terms
Work-holding devices	3172.1 Vises 3172.2 Table mounting and clamping devices 3172.3 Index centres	312.3	Hold-downs Strap clamps U clamps Goose-neck clamps Toe dogs Poppets Jacks
Trac[illegible]	3181.1 Contour turning on the lathe 3181.2 Contour milling on vertical mill 3181.3 Pantograph	31.1 31.2 31.5	Hydraulic piston Servo valve, stylus Master (flat template) Master (cylindrical) Parallelogram Ratio Stylus Template Sulphur cast Master pattern
Turret lathe	3182.1 Types 3182.2 Purpose 3182.3 Description	31.1	Horizontal turret Vertical turret Ram-type Saddle-type Multi-spindle
Screw machines (O)	3183.1 Types 3183.2 Purpose 3183.3 Description	133.2	Swiss-type automatic Single-spindle automatic Plate cam Drum cams Indexing

Fundamentals	Suggestions for Student Activity	D
The holding of a workpiece rigidly, accurately and without distortion.		
The accurate reproduction of a workpiece from a master. Contours Use of the parallelogram principle for the accurate reproduction of a workpiece from a master.	**CONTOUR TURNING (ME)** • make a master and then reproduce a workpiece from it.	The student should know ho and work so that the cutting t 2 or 3 dimensional contact Ratio between size of cutte Adjustment for 2 or 3 dime
Multiple tooling eliminates tool change by operator.	**TURRET LATHE OPERATIONS (ME)** • set-up the turret lathe for the machining of various small parts on production basis.	The use of audio-visual aid cation assignments will incr and automatic screw machin Note that screw machines u precedes modern computer
Automatic production of small pieces at high production rates through successive or simultaneous use of turrets and cross slides. Programming (C)	**SCREW MACHINES (A)** • make a research study of the development and industrial impact of automatic screw machines.	

Suggestions for Student Activity	Discussion
R TURNING (ME) a master and then reproduce a workpiece from it.	The student should know how to establish a starting position for master and work so that the cutting tool will contact the work correctly: 2 or 3 dimensional contact pressure Ratio between size of cutter and stylus Adjustment for 2 or 3 dimensional work
LATHE OPERATIONS (ME) the turret lathe for the machining of various small parts ction basis.	The use of audio-visual aids, field trips, work study programs and application assignments will increase the interest of the student in turret lathe and automatic screw machine operations. Note that screw machines use a form of mechanical programming which precedes modern computer programming.
MACHINES (A) a research study of the development and industrial impact atic screw machines.	

Section	Topic	Element
31.8 Special processes (continued)	**318.4 Boring mills (O)**	3184.1 Types 3184.2 Purpose 3184.3 Description
	318.5 Numerical control (N/C)	3185.1 Purpose and description of N/C systems 3185.2 Programming 3185.3 Tape preparation
	318.6 Electrodischarge machining (E.D.M.)	3186.1 Purpose and description of E.D.M. 3186.2 Operation
	318.7 Electrochemical machining (E.C.M.)	3187.1 Purpose and description 3187.2 Operation
	318.8 Ultra-sonic machining (U.S.M.) (O)	3188.1 Purpose and description 3188.2 Operation

UNIT: 3.1 Machining Operations

Topic	Element	Cross-Reference	Technical Terms
8.4 Boring mills (O)	3184.1 Types 3184.2 Purpose 3184.3 Description	31.1	
8.5 Numerical control (N/C)	3185.1 Purpose and description of N/C systems 3185.2 Programming 3185.3 Tape preparation	31.2	Point-to-point Continuous path Programmed numerical data Punched tape, card Analog and digital transducer Feedback signals Open loop, closed loop Servo control Indexer
8.6 Electrodischarge machining (E.D.M.)	3186.1 Purpose and description of E.D.M. 3186.2 Operation	1222.2	Electrode Dielectric fluid Servo-mechanism
8.7 Electrochemical machining (E.C.M.)	3187.1 Purpose and description 3187.2 Operation	1222.3 126.2	Electroplating bath Electrolyte solution Electrode tool Overcut
8.8 Ultra-sonic machining (U.S.M.) (O)	3188.1 Purpose and description 3188.2 Operation		Electronic generator Transducer Boron carbide Silicon carbide Aluminum oxide Bombardment Cavitation

Fundamentals	Suggestions for Student Activity	
Material removal from a relatively large workpiece by a cutting tool (usually single point).		While it is improbable performed in the scho students with their pri films, E.T.V., and field plants. The following points mi Binary coded decima Absolute digital sys Incremental digital r Analog method Discharge of very sh Resistance — capac Pulse type circuit Metal removal rates Electrode wear Surface finish Electrical and chemi Cutting tool never to Ratio of stock remov Penetration rates Students should be enc new machining method
Automatic control of machine motions by a series of programmed instructions. Transducers Feedback (C)		
Removal of metal by means of an electrical discharge.	**SPECIAL MACHINING PROCESSES (A)** • make an application study of new methods of metal removal.	
Electrochemical process.		
Material removal by high frequency mechanical vibrations.		

uggestions for Student Activity	Discussion
	While it is improbable that many of these new machining processes can be performed in the schools, every effort should be made to acquaint the students with their principles of design and operation by the viewing of films, E.T.V., and field trips to machinery exhibitions and manufacturing plants. The following points might be discussed: Binary coded decimal system Absolute digital system Incremental digital method Analog method Discharge of very short duration and very high current density Resistance — capacitance circuit Pulse type circuit Metal removal rates Electrode wear Surface finish Electrical and chemical energy used as cutting tools Cutting tool never touches the work Ratio of stock removal to tool wear Penetration rates Students should be encouraged to make an in-depth study of any one of the new machining methods listed under "topic".

CHINING PROCESSES (A)

plication study of new methods of metal removal.

DIVISION 3: Machine Theory and Practice

UNIT

Section	Topic	Element
32.1 Layout	321.1 Surface preparation	3211.1 Media
	321.2 Tools and equipment	3212.1 Measuring tools 3212.2 Marking tools 3212.3 Auxiliary tools and devices
32.2 Fitting and assembling	322.1 Cutting tools	3221.1 Hand tools 3221.2 Power tools
	322.2 Assembly devices and methods	3222.1 Threaded fastening devices 3222.2 Other fastening devices 3222.3 Standard fits and clearances

UNIT: 3.2 Bench Operations

Topic	Element	Cross-Reference	Technical Terms
urface reparation	3211.1 Media		Layout blue, copper sulphate whiting Heating to colour
ools and quipment	3212.1 Measuring tools 3212.2 Marking tools 3212.3 Auxiliary tools and devices	127.3	Line-graduated, keyseat rule, shrink rule, Vernier bevel Protractor, sine bar, gauge blocks, Vernier height gauge Box parallels, angle plate, V-blocks, surface plate, layout template
utting tools	3221.1 Hand tools 3221.2 Power tools		Chipping, scraping, needle files, riffler files
ssembly devices nd methods	3222.1 Threaded fastening devices 3222.2 Other fastening devices 3222.3 Standard fits and clearances	125.3 125.2 211.5	Keys, circlips, basic dimension, mean dimension, tolerance, allowance limit

Fundamentals	Suggestions for Student Activity	
Surface conditions	**LAYOUT (P)** • lay out and prepare the details, or component parts, of a project or projects of sufficient complexity to involve the student in the use of the widest possible range of measuring and layout tools.	The need for accuracy sho that this is a primary functio by the quality of the layout. The relationship to blueprint The choice of instruments
Metrology		
The skill of the craftsman determines the resultant accuracy.	**FITTING (P)** • bench-in a die cavity. • fit and assemble a drill jig.	
Rotary, reciprocating, permanent and screw thread fits.	**ASSEMBLY (E)** • strip and re-assemble an index head. • strip and re-assemble a lathe carriage.	Cleanliness and care in fittin

estions for Student Activity	Discussion
pare the details, or component parts, of a project icient complexity to involve the student in the use sible range of measuring and layout tools.	The need for accuracy should be stressed. The student must understand that this is a primary function and that the final result is largely determined by the quality of the layout. The relationship to blueprint and drafting techniques should be emphasized. The choice of instruments or tools depends upon the accuracy required.
cavity. e a drill jig.	
semble an index head. semble a lathe carriage.	Cleanliness and care in fitting is a paramount consideration.

DIVISION 3: Machine Theory and Practice

Section	Topic	Element
33.1 Measurement and gauging	331.1 Science of measurement	3311.1 Measurement for progress 3311.2 Language of measurement
	331.2 Measuring instruments	3312.1 Linear 3312.2 Angular 3312.3 Thread and gear
	331.3 Gauging equipment	3313.1 Gauge blocks and measuring rods 3313.2 Dial indicators 3313.3 High amplification comparator 3313.4 Optical flats 3313.5 Transfer gauges 3313.6 Surface measurement 3313.7 Interferometry 3313.8 Optical measurement
33.2 Testing	332.1 Non-destructive	3321.1 Hardness testing 3321.2 Crack testing 3321.3 X-ray
	332.2 Destructive	3322.1 Tensile testing 3322.2 Compression testing 3322.3 Impact testing 3322.4 Shear testing 3322.5 Environmental

UNIT: 3.3 Metrology

Topic	Element	Cross-Reference	Technical Terms
Science of measurement	3311.1 Measurement for progress	12.7	Light wave Interferometry
	3311.2 Language of measurement	23.3	
Measuring instruments	3312.1 Linear	12.7	Three-wire Chordal thickness Corrected addendum
	3312.2 Angular	3151.3	
	3312.3 Thread and gear		
Gauging equipment	3313.1 Gauge blocks and measuring rods	12.7	Wiring Mechanical advantage Fulcrum Lens — focal distance — magnification image Microinch Profilometer Lay Flaw Wave Flat — optical flat
	3313.2 Dial indicators		
	3313.3 High amplification comparators		
	3313.4 Optical flats		
	3313.5 Transfer gauges		
	3313.6 Surface measurement		
	3313.7 Interferometry	315.4	
	3313.8 Optical measurement	3124.6	
Non-destructive	3321.1 Hardness testing	113.2	Minor load Major load Braille X-ray Ultrasonics Cathode-rays
	3321.2 Crack testing	113.3	
	3321.3 X-ray	125.1	
Destructive	3322.1 Tensile testing	1111.5	Test piece Gauge points Elongation Cross-sectional area Izod — notch
	3322.2 Compression testing	1112.5	
	3322.3 Impact testing	22.2	
	3322.4 Shear testing		
	3322.5 Environmental		

Fundamentals	Suggestions for Student Activity	
Standards	**MEASUREMENT (A) (E)** • make a comparative study of measurement systems. **MEASUREMENT (E)** • establish within the class group the degree of interchangeability possible if each student's forearm (cubit) were the standard of measurement.	The student ability — m lent vehicle in the resol Precision m tions of cle
Vernier Principle Trigonometric functions $G = \frac{.57735}{N}$ $M = D + 3G - \frac{1.5155}{N}$	**MEASUREMENT (A)** • relate dimensional control and interchangeable mass production. **MEASUREMENT (E)** • read a Vernier caliper. • measure a thread using three-wire method. • measure a gear tooth: wire and caliper. • make a gauge block build-up. • study the effect of temperature on gauge block build-ups. • set up a sine bar. • make comparative measurements with a dial indicator.	
Law of Levers Root-mean-square system Wave interference		
Law of Levers Hardness Fluorescence Pascal's Law Young's Modulus of Elasticity	**TESTING (E)** • test the hardness of a metal. • carry out the following tests: Tensile Compressive Impact Shear Environmental	Relationshi Every effor chemistry a
Stress — strain relationship		

Suggestions for Student Activity	Discussion
EMENT (A) (E) a comparative study of measurement systems. **EMENT (E)** ish within the class group the degree of interchangeability if each student's forearm (cubit) were the standard urement.	The student must understand the role of measurement in the interchangeability — mass production — cost triangle. Metrology presents an excellent vehicle for the demonstration of physical and mathematical concepts in the resolution of technical problems. Precision measurement is only possible under carefully controlled conditions of cleanliness and temperature.
EMENT (A) dimensional control and interchangeable mass pro- **EMENT (E)** Vernier caliper. re a thread using three-wire method. re a gear tooth: wire and caliper. gauge block build-up. he effect of temperature on gauge block build-ups. a sine bar. comparative measurements with a dial indicator.	
(E) e hardness of a metal. ut the following tests: essive mental	Relationship between hardness and tensile strength should be shown. Every effort should be made to relate material to the student's studies in chemistry and physics.